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OUTLINE FACTS
OF
CHEMISTRY
With Exercises.

OUTLINE FACTS

OF

CHEMISTRY,

WITH EXERCISES.

INTENDED CHIEFLY FOR PUPILS IN GOVERNMENT SCIENCE CLASSES.

BY T. WARD, F.C.S.,
TEACHER OF CHEMISTRY AT THE MECHANICS' INSTITUTION, BOLTON,
AND THE ATHENÆUM, BURY.

PARTS I. & II.

BIBLIOTHECA BODLEIANA

London:
SIMPKIN, MARSHALL, & CO.
MANCHESTER: JOHN HEYWOOD.
1866.

193. g. 16.

PREFACE.

THIS little work has been prepared mainly to serve the purpose of a note book, so that *conciseness* has been aimed at throughout. Chemical apparatus is now so commonly used, that no attempt has been made to describe it; neither has the author thought it necessary to give lengthened accounts of chemical manipulation, which, it is presumed, is seen in the lecture-room. Bolder type distinguishes the more important facts, and thus furnishes a first course for beginners.

Tables of Formulæ have been introduced to make the pupil familiar with them at an early stage, and to assist the teacher in giving exercises in calculating percentages. It is hoped that the Exercises at the end will be found of service in preparing for Examinations.

The New Notation and Nomenclature have been adopted.

The temperatures are given on Fahrenheit's scale, but the annexed table will enable the student to convert them into Centigrade.

The writer begs to acknowledge the important aid he has received from the following recent works on Chemistry, "Watt's Dictionary," "Miller's Elements of Chemistry," "Brande and Taylor's Chemistry," "Williamson's Chemistry," "Hoffman's Modern Chemistry," "Abel and Bloxam's Handbook of Chemistry," and "Fownes's Manual of Chemistry."

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(A) (B)

...$N_2O = 28 + 16$
...$N_2O_2 = 28 + 32$
...$N_2O_3 = 28 + 48$
...$N_2O_4 = 28 + 64$
....$N_2O_5 = 28 + 80$

DEFINITIONS, &c.

1. The science of **Chemistry** makes us acquainted with the properties of the various elementary bodies in nature, their actions on each other, the products which they form, and the laws which regulate their action. *Thomson.*

2. **Organic Chemistry** treats of those substances which are produced directly, or indirectly, by the *vital processes* in animals or vegetables. Bodies otherwise obtained are embraced by **Inorganic Chemistry.**

3. **An Element** is a simple form of matter which cannot be resolved into any other kind of matter.

Sixty-three elements are at present known.

4. **The Metals or Metallic Elements** are distinguished by—1. A peculiar lustre. 2. Their opacity. 3. Their high conducting powers in regard to heat and electricity. 4. Ductility. 5. Malleability. 6. High specific gravity. 7. Tenacity.

The following is a list of the metals, Potassium, Sodium, Lithium, Cæsium, Rubidium; Barium, Strontium, Calcium; Aluminum, Glucinum, Zirconium, Thorinum, Yttrium, Erbium, Terbium, Cerium, Lanthanum, Didymium; Magnesium, Zinc, Cadmium; Cobalt, Nickel, Uranium, Iron, Chromium, Manganese; Tin, Titanium, Columbium, Tantalum, Molybdenum, Vanadium, Tungsten, Arsenicum, Antimony, Bismuth; Copper, Lead, Thallium; Mercury, Silver, Gold, Platinum, Palladium, Rhodium, Ruthenium, Osmium, Iridium.

5. **The Non-Metallic Elements or Metalloids** embrace the rest of the elements.

They are Oxygen, Hydrogen, Nitrogen, Carbon, Chlorine, Bromine, Iodine, Fluorine, Sulphur, Selenium, Tellurium, Phosphorus, Boron and Silicon.

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25. Table of Elements—Metalloids.

	Sym.	At. Wt.		Sym.	At. Wt.
Oxygen	O	16	Bromine	Br	80
Hydrogen	H	1	Iodine	I	127
Nitrogen or *Azote*	N	14	Fluorine	F	19
Sulphur	S	32	Boron	B	10.9
Phosphorus	P	31	Silicon	Si	28
Carbon	C	12	Selenium*	Se	79.5
Chlorine	Cl	35.5	Tellurium*	Te	129

Metals.

Potassium(*Kalium*)	K	39.1	Iron (*Ferrum*)	Fe	56
Sodium (*Natrium*)	Na	23	Chromium	Cr	52.5
Lithium*	Li	7	Manganese	Mn	55
Cæsium*	Cs	133	Tin (*Stannum*)	Sn	118
Rubidium*	Rb	85.4	Titanium	Ti	50
Barium	Ba	137	Molybdenum*	Mo	96
Strontium	Sr	87.5	Tungsten or		
Calcium	Ca	40	*Wolfram*	W	184
Aluminum	Al	27.5	Vanadium*	V	137
Magnesium	Mg	24	Arsenicum	As	75
Glucinum*	G	9.5	Antimony(*Stibium*)	Sb	122
Zirconium*	Zr	89.5	Bismuth	Bi	210
Thorinum*	Th	119	Copper (*Cuprum*)	Cu	63.5
Lanthanum*	Ln	92.8	Lead (*Plumbum*)	Pb	207
Yttrium*	Y		Thallium*[*gyrum*)	Tl	204
Erbium*	E		Mercury (*Hydrar-*	Hg	200
Terbium*	Tr		Silver (*Argentum*)	Ag	108
Cerium*	Ce	92	Gold (*Aurum*)	Au	196.7
Didymium*	Di	96	Platinum	Pt	197.1
Zinc	Zn	65	Palladium*	Pd	106.5
Cadmium*	Cd	112	Rhodium*	Ro	104.3
Cobalt	Co	59	Ruthenium*	Ru	104.2
Nickel	Ni	59	Osmium*	Os	199
Uranium*	U	120	Iridium* [*bium*)	Ir	197.1
Tantalum*	Ta	137.6	Niobium*(*Colum-*	Nb	

* Rarer Elements.

26. **Notation.** The names of the elements are represented by letters called their Symbols. (*See Table of Elements.*)

A Symbol also represents *one atom* of the element indicated, as C for example, means one atom of Carbon. The *Molecule* of a free element is represented by a double letter, as H H, a molecule of Hydrogen.

Compound bodies are represented by placing together the symbols of their components, as Na Cl for one molecule of Common Salt, or Chloride of Sodium.

In compounds containing metals, the symbol for the metal is placed first.

Ex.—$Ba\ SO_4$ Sulphate of Barium.

When there is more than one atom of an element in a molecule, it is shown by a small figure, or index to the right of the symbol, as $H_2\ O$, water, which means, that there are two atoms of hydrogen in a molecule of water.

A large figure to the left of the symbols, indicates the number of molecules in a compound.

Ex.—5 CO_2 represents 5 molecules of Carbonic Anhydride.

A large figure preceding a bracket multiplies all the symbols within the bracket

Ex.—$6\ (Na_2\ CO_3\ 10H_2O)$ means 6 atoms of Carbonate of Sodium.

The union of one compound with another is expressed by a + (*plus sign*) or a , (*comma*).

27. **Nomenclature. Oxides** contain oxygen in combination with another element, generally a metal. The proportion of oxygen in an oxide is indicated generally, by a prefix, as **sub, sesqui,** &c.

A **Suboxide** is formed by an atom of a *diatomic* metal uniting with an atom of oxygen, as Mercurous Oxide $Hg_2\ O$. The diatomic metal in this case, is only equal to one atom of Hydrogen.

A **Monoxide** or **Protoxide** contains either (*a*) *one* atom of a *diatomic* metal, or (*b*) *two* atoms of a *monatomic* metal with one atom of oxygen.

Exs.—*a*. Cupric oxide, CuO. *b*. Soda, $Na_2\ O$.

In the *hydrate* of the latter, one atom of sodium is replaced by atom of hydrogen, as follows,

$$\left.\begin{matrix}Na\\Na\end{matrix}\right\}O \text{ becoming } \left.\begin{matrix}Na\\H\end{matrix}\right\}O.$$

A **Sesquioxide** is formed by the combination of *one* atom and a *h* of oxygen with *one* atom of a *diatomic* metal.

Ex.—Alumina $Al_2 O_3$ (both numbers are doubled to avoid the fractio $1\frac{1}{2}$).

A **Binoxide** or **Dioxide** contains *two* atoms of oxygen with *one* ato of a *diatomic* metal, or two of a *monatomic* metal.

Exs.—Peroxide of silver, $Ag_2 O_2$; peroxide of barium, Ba O **Deutoxide** is synonymous with binoxide. **Peroxide** means the *high* oxide.

An *acid* oxide is sometimes distinguished as an **electro-negati** oxide, and a *basic* oxide, as **electro-positive.**

Sulphides consist of sulphur in combination with some other elemen generally a metal.

Exs.—Sulphide of mercury, Hg S; Bisulphide of platinum, PtS Persulphide of gold, $Au_2 S_3$

Chlorides, Phosphides, &c., contain Chlorine and Phosphor &c., respectively in combination with some other element.

Exs.—Subchloride of silver, Ag_2 Cl; Bichloride of platinum, Pt Cl Fluoride of calcium, Ca F_2

Acids.—Acids containing oxygen as an essential element are call **Oxyacids**, whilst those which contain hydrogen as essential, are know as **Hydracids.**

Acids without water are termed, **Anhydrides.**

Exs.—*Oxyacids*—Sulphuric Acid, $H_2 SO_4$; Nitric Acid $H NO_3$
Hydracids—Hydrochloric Acid, HCl; Iodic Acid, $H IO_3$
Anhydrides—Carbonic anhydride, CO_2; Sulphuric anhydride, SO_3

When the name of an acid ends in **ic** it signifies that it contains mo oxygen than another ending in **ous.**

Exs.—Sulphurous anhydride, SO_2; Sulphuric acid, $H_2 SO_4$

An acid containing more oxygen than is represented by ic is prefixe by **per**; if it contain less than is expressed by ous, **hypo** is prefixed.

Exs.—Hypochlorous acid, HClO; Chlorous acid, $HClO^2$; Chlor acid, $HClO_3$; Perchloric acid $HClO_4$

Hydro is prefixed to the hydracids as Hydrobromic acid, HBr.

Monobasic Acids contain in a molecule, *one* atom of Hydrogen, ich may be replaced by a *monatomic* metal as Nitric Acid, HNO_3, the drogen of which may be replaced by Sodium forming the Nitrate of dium, $NaNO_3$

Dibasic Acids contain in a molecule, *two* atoms of Hydrogen which y be replaced either by *two* atoms of a *monatomic* metal like Sodium, or e atom of a *diatomic* metal like Zinc.

Ex.—Sulphuric Acid, $H_2\,SO_4$ with Sodium forms Sulphate of Sodium, $_2\,SO_4$ and with Zinc, Sulphate of Zinc, $Zn\,SO_4$.

Tribasic Acids contain in a molecule, *three* atoms of Hydrogen ich may be replaced by *three* atoms of a *monatomic* metal, or *one* atom a *triatomic* metal.

Ex.—Phosphoric Acid, $H_3\,PO_4$ may have its three atoms of Hydrogen placed by three atoms of Sodium, forming Phosphate of Sodium, $_3\,PO_4$, or *one* atom of Bismuth forming Phosphate of Bismuth, $Bi\,PO_4$

When *more* than *one* atom of Hydrogen in an acid is displaced by a nilar number of atoms of a metal, it is called **Polybasic.**

Bases. A *Base* or *Basyl* may consist of a *metal*, or a *compound* uivalent to a metal.

Exs.—Nitrate of sodium, $Na\,NO_3$; Nitrate of ammonium $H_4\,N\,NO_3$

Salts—Oxysalts are such as contain an oxide, in combination with *oxyacid* or *anhydride.*

Haloid Salts consist of a metal combined with one of the *halogens.* *ee par.* 21.)

Exs.—*Oxysalt*—Sulphate of potassium, $K_2\,SO_4$; *Haloid Salt*—uoride of Calcium, CaF

When an acid ends in *ic*, the salt derived from it terminates in **ate.**

Ex.—Sulph**ate** of sodium is derived from sulphur*ic* acid.

When an acid ends in *ous*, the salt derived from it terminates in **ite.**

Ex.—Sulph**ite** of sodium is formed from sulphur*ous* acid.

Neutral or **Normal Salts** are such as do not, when dissolved, ange the colour of litmus paper.

The solutions of Acid Salts change a *blue* litmus paper to *red*.

Basic Salts change a *red* litmus paper to *blue*.

When the hydrogen in a *monobasic* acid is replaced by a *monad*, or that of a *bibasic* acid by a *dyad*, the salt is called *normal* or *neutral*, although it may change the colour of litmus paper. In nitrate of lead, for instance, the *dyad* lead, occupies the place of two atoms of hydrogen, $2H\ NO_3$ becoming $Pb2NO_3$ This is said to be a normal or neutral salt, and yet it reddens litmus paper. Change of colour of litmus, therefore, must only be considered as a general proof of acidity or neutrality.

28. **Formulæ.—Empirical Formula** is the representation of the composition of a body by its symbols, showing simply what elements it contains, and the proportions of each. **Rational Formula** is such a representation by symbols, as indicates some theory as to the manner in which the elements are united in a compound.

Nitrate of Calcium is found by analysis to contain $Ca\ N_2\ O_{10}\ H_8$ so that these symbols indicate its *empirical formula*, but on the supposition that Nitric Acid is combined with lime and water, the symbols may be thus arranged, $CaO,\ NO_5\ 4HO$, which is its *rational formula*, or as is now done, supposing that the acid and base are arranged differently when *united*, from what they are when *separate*, the rational formula may be given thus—

$$Ca\ NO_3\ 4H_2\ O.$$

29. **Crystallisation. A Crystal** is a solid body, bounded by plane surfaces, disposed according to a regular law of symmetry, the form thus produced being essentially related to the composition and properties of the body, so that the minutest particles into which the body can be mechanically divided exhibit either the same form or one related to it by determinate laws. WATTS.

System 1.—Cubic, Octahedral, Tessular or **Regular,** having 3 rectangular axes, all equal.

Allied Forms—1 Cube. 2 Regular Octahedron. 3 Tetrahedron. Rhombic Dodecahedron. 5 Trapezohedron.

Exs.—Copper, Nickel, Gold, Lead, Alum, Common Salt, Arsenious Acid, Diamond, Fluorspar, Iron Pyrites and Garnet.

System 2.—Right Square Prismatic, having 3 rectangular axes, 2 equal.

Allied Forms—6 Square Prism. 7 Octahedron, with a square base.

Exs.—Ferrocyanide of Potassium, Cyanide of Mercury, Calomel and Tin.

System 3.—Rhombohedral, having 3 equal axes not rectangular, intersecting at 60°, one perpendicular to the three.

Allied Forms—8 Rhombohedron. 9 Bipyramidal Dodecahedron. 10 Hexahedral Prism.

Exs.—Calcareous Spar, Nitrate of Sodium, Ice, Camphor, Tourmaline, Quartz, Amethyst, Emerald, Corundum and Graphite.

System 4.—Right Rectangular, or **Rhombic Prismatic,** having 3 rectangular axes, no two equal.

Allied Forms—11 Right Rectangular Prism. 12 Right Rhombic Prism. 13 Right Rectangular Octahedron. 14 Right Rhombic Octahedron.

Exs.—Sulphur, Nitre, Rochelle Salts, Topaz, Arragonite, Bichromate of Potassium, Citric Acid, Sulphates of Magnesium, Barium, Potassium and Zinc.

System 5.—Oblique Rectangular, or **Rhombic Prismatic,** having 2 axes oblique, the third perpendicular to both.

Allied Forms—15 Oblique Rectangular Prism. 16 do. Rhombic Prism. 17 do. Rectangular Octohedron. 18 do. Rhombic Octohedron.

Exs.—Felspar, Mica, Epidote, Sulphate and Carbonate of Sodium, Chlorate of Potassium, Borax, Sugar, Sulphur, Sulphate of Lime and Oxalic Acid.

System 6.—Doubly Oblique Prismatic, having 3 axes, all intersecting each other obliquely.

Allied Forms.—19 Doubly Oblique Prism. 20 Doubly Oblique Octahedron.

Exs.—Sulphates of Copper and Iron, and Nitrate of Bismuth.

NON-METALLIC ELEMENTS.

30. Oxygen.

Eq., 16; Sym., O; Atom. Vol., □; Sp. Gr., 1.1057.

This element is when pure, a colourless and tasteless *gas*. Its most striking property is that of supporting combustion and animal life. It forms more than one-fifth the weight of the atmosphere and eight-ninths that of water. It is, however, never found *free* in nature, but is readily prepared by heating a mixture of the chlorate of potassium and black oxide of manganese, both finely powdered. The following equation represents the chemical re-action.

(1.)—$2KCl\,O_3 + Mn\,O_2 = 2KCl + 3O_2 + Mn\,O_2$.

Oxygen has never been liquified; is not combustible but supports combustion, as strikingly seen when phosphorus, sulphur, iron wire, &c., are burnt in a jar of the gas; combines with every other element except Fluorine; supports animal life, hence called *vital air*; water absorbs only $\frac{1}{25}$ its bulk at 32°; 100 cu. in. weigh 34.203 grains; forms basic, neutral, and acid oxides; rapidly compressed, its temperature rises to 400°; is most magnetic of all gases. Discovered by DR. PRIESTLY, and by SCHEELE, independently of each other, in 1774.

Preparations—Other Methods.

2.—By heating the Red Oxide of Mercury to 700° or 800° (F.)

$$2HgO = 2Hg + O_2$$

3.—By heating the Binoxide of Manganese in an iron bottle.

$$3MnO_2 = Mn_3\,O_4 + O_2$$

1℔ of the Oxide is said to yield 5 gallons of Oxygen.

4.—By the decomposition of water by electricity.

$$H_2\,O = H_2 + O.$$

5.—By heating the Chlorate of Potassium in a flask.

$$2KClO_3 = 2KCl + 3O_2$$

1oz. of the Salt yields nearly 2 gallons of oxygen.

6.—By heating Sulphate of Zinc to red heat.

$$2ZnSO_4 = 2ZnO + 2SO_2 + O_2$$

7.—By heating Sulphuric Acid with half its weight of Acid Chromate of Potassium, or Black Oxide of Manganese.

$$2K_2\,Cr_2\,O_7 + 10H_2\,SO_4 = 4KHSO_4,\ 2\,(Cr_2\,3SO_4) + 8H_2\,O + 3O_2$$

8.—By heating Sulphuric Acid so as to decompose it.

$$2H_2SO_4 = 2H_2O + 2SO_2 + O_2$$

1 fluid ounce of Acid yields 360 cu. in. of Oxygen.

9.—By raising Baryta to the Peroxide of Barium, by heating it in a current of air, and then to decompose it by a higher temperature.

10.—By heating to 70° or 80° a strong solution of Chloride of Lime containing a little freshly prepared Peroxide of Cobalt.

Tests.—Should readily re-kindle a glowing match ; forms red fumes with nitric oxide.

Ozone.—This is supposed to be Oxygen in a more active condition ; may be prepared by placing clean Phosphorus moistened with a little water, in a bottle of Atmospheric Air, or by passing Electricity through dry Oxygen. It has a peculiar smell like weak Chlorine ; insoluble in water ; irritates the lungs ; powerful bleacher ; liberates Iodine from Iodide of Potassium, hence paper moistened with Iodide of Potassium and starch is a good *test* for Ozone.

Antozone.—This is supposed by Schönbein to be an opposite form of *Ozone*, but Von Babo has shewn it to be Peroxide of Hydrogen.

31. Hydrogen.

Eq. 1 ; Sym., H ; Atom. Vol. □ ; Sp. Gr., 0.0692.

Hydrogen is a colourless, tasteless, and inodorous *gas*. It is inflammable but does not support combustion. It forms an important part of nearly all combustible bodies. It is also the lightest body known, being only $\frac{1}{15}$ the weight of air. It is not met with in a *free* state, but is readily obtained by the decomposition of water. The common method is to add oil of vitriol to a few pieces of zinc or iron and a little water in a bottle, *without* heat. The following reaction takes place.

$$H_2SO_4 + Zn = ZnSO_4 + H_2$$

1oz. of zinc should yield 2½ gallons of hydrogen.

Hydrogen has never been liquified; 100 cu. in. of water only absorbs 1.93 cu. in. of H when temperature is between 32° and 68°; 100 cu. in. weigh 2·14 grains; its lightness may be illustrated by filling a balloon; does not sustain life; burns with yellow flame; flame gives little light, but great heat. When oxygen is made to combine with the hydrogen flame it is known as the *oxyhydrogen jet*; this jet received on lime gives an intense light, called the *Drummond* light. Readily penetrates paper; if two-thirds Hydrogen are mixed with one-third oxygen and a light applied, the mixture will explode; produces musical sounds when burnt in a glass tube; combines with oxygen in presence of spongy platinum, and raises the platinum to a red heat; when burnt in combination with oxygen, as in Hemming's Safety Jet, it gives intense heat. Discovered by Cavendish in 1766.

Preparations.—2. By decomposition of water, using the voltaic battery. $H_2 O = H_2 + O$.

3.—By decomposing water with potassium.

$$H^2 O + K_2 = K_2 O + H_2$$

4.—By passing steam through a red-hot tube containing iron filings.

$$3Fe + 4H_2 O = FeO, Fe_2 O_3 + 4H_2$$

5.—By passing steam over charcoal heated to a dull red heat.

$$2H_2 O + C = 2H_2 + CO_2$$

6.—By heating zinc with a solution of hydrate of potash.

$$2KHO + Zn = K_2 ZnO_2 + H_2$$

7.—By heating formates or oxalates with excess of hydrate of potassium, sodium, or calcium. $KCHO_2 + KHO = K^2 CO^3 + H_2$

Tests.—Inflammable; burnt with half its volume of oxygen forms water; lightest body known.

32. Water.

Eq., 18; Sym., $H_2 O$; Com. Vol. as Vapour, 2, or □□; Sp. Gr. as Vapour 0·622, as Liquid 1·0, as Ice 0·918.

Water may be shown both by analysis and synthesis to consist of two volumes or equivalents of hydrogen combined with *one* volume or equivalent of oxygen, *condensed* to *two* volumes. **Rain Water** is the purest kind of natural water. **Spring Water** always contains in solution small quantities of such salts as carbonate of sodium, chloride of sodium, carbonate of magnesium, carbonate and sulphate of calcium; it generally contains, too, a quantity of carbonic anhydride. When spring water is charged with a large proportion of saline or earthy matter, it is called **Mineral Water,** as *chalybeate,* containing *iron*, *sulphureous* containing *sulphuretted hydrogen* **Sea Water** holds in solution a large per centage of common salt, chloride of magnesium, sulphate of magnesium, &c.

At usual temperature, when quite pure, water is clear, transparent, colourless, tasteless and odourless; below 32°(F.)it freezes; evaporates at all temperatures; boils at 212° with usual pressure of air; a cu. in. at 60° weighs 252·456 grains; contains 16 parts by weight of Oxygen and 2 of Hydrogen, hence might be called the protoxide of Hydrogen; it is perfectly neutral; may be decomposed by bodies having strong affinity for Oxygen; united with other compounds it forms *hydrates*; such compounds free from water are *anhydrous*; it is an excellent *solvent*; it is got quite pure by *distillation*; when it contains lime, as seen by causing soap to curd, it is called *hard*; it expands when frozen. CAVENDISH demonstrated its composition in 1781.

33. Peroxide or Deutoxide of Hydrogen, Hydric Peroxide, or Oxygenated Water.

H_2O_2 . Sp. Gr. of liquid 1·453.

This is a colourless liquid having a syrupy consistence; has smell of chlorine; remains liquid at —22° (F.); heated to 70° (F.) oxygen is given off; is miscible in all proportions with water; does not redden litmus but slowly bleaches both litmus and tumeric paper.

This compound is prepared by passing Oxygen over Caustic Baryta heated to redness, which yields BaO_2, then adding water which forms the Hydrate of Baryta, $BaO_2\ 6H_2O$, and afterwards decomposing this latter body by Hydrochloric Acid.

$$BaO\ \ 6H_2O + 2HCl = H_2O_2 + 6H_2O + BaCl_2$$

34. Nitrogen or Azote.

Eq., 14 ; Sym., N ; Atom. Vol., □ ; Sp. Gr., 0·9713.

This gas is neither combustible nor a supporter of combustion. It forms about four-fifths by volume of the atmosphere, and answers an important purpose in diluting the oxygen so as to render it fit for constant respiration. It is one of the most important constituents of plants and animals. It is most commonly obtained by removing the oxygen from atmospheric air. This is done by burning phosphorus in a dish floating on water, and covering it with a jar filled with air.

$$(1.)—\text{Air} + P = N + P_2 O_5$$

This gas has never been liquified; 100 cu. in. weigh 30·119 grains at 60°; when alone, does not sustain animal life, hence called *Azote*; water dissolves $\frac{1}{50}$ of its bulk, at common temperatures; is a neutral body; has neither colour, taste, nor smell; exists in small quantity in all plants; forms important compounds with Oxygen and Hydrogen as Nitric Acid and Ammonia. Discovered by RUTHERFORD in 1772.

Other Modes of Preparation.—2.—By passing Chlorine into a solution of Ammonia.

$$2H_3 N + 3Cl_2 = 6HCl + N_2$$

If the process is carried too far, an explosive compound is formed, the Chloride of Nitrogen.

3.—By heating the Nitrite of Ammonium.

$$H_4 N NO_2 = 2H_2 O + N_2$$

4.—By passing air over heated copper, finely divided. This method supplies it in large quantities.

5.—By placing in a jar of air a piece of Phosphorus, moistened iron filings, lead shavings, or sulphides of the alkaline metals.

6.—By putting a jar of air over an evaporating dish containing a mixture of Pyrogallic Acid, and a strong solution of Potash.

Tests.—Extinguishes burning bodies, and does not render lime water turbid; it may be converted into Ammonia by heating a substance containing it with soda and lime, and is then distinguished by the Ammonia Tests. —Par. 42.

35. The Atmosphere.

The Air is a *mixture* of the two gases Oxygen and Nitrogen. In 100 parts by *measure*, 79.19 are nitrogen and 20.81 are oxygen. In 100 parts by *weight*, 76.99 are nitrogen and 23.01 are oxygen. Specimens examined in different parts of the world have been found to vary but very slightly. Carbonic Anhydride, watery vapour and Ammonia are found in small quantities diffused in the atmosphere.

The atmosphere contains 3 to 6 parts in 10,000 of Carbonic Acid, and small portions of Watery Vapour, Nitric Acid, Ammonia, Carburetted Hydrogen, Sulphuretted Hydrogen, Sulphurous Acid, and Organic impurities; the proportion of Oxygen in the Air may be seen in the fifth method of obtaining Nitrogen, by the rising of the water in the tube about one-fifth; this may be shown more correctly by exploding 50 measures of Hydrogen with the Oxygen of 100 measures of Air in a Ure's Eudiometer.

Air in Eudiometer	100 measures.
Hydrogen added	50 „
	150
After Explosion	87
Diminution	63

This divided by 3 (the steam formed being composed of 2 vols. Hydrogen and 1 vol. Oxygen) gives 21 measures of Oxygen in 100 measures of air.

36. Nitric Acid, or Hydrated Nitric Acid.

Sym., HNO_3; Eq., 63; Sp. Gr. of Liquid, 1.517; Boil. Pt. 184° F.

This liquid is sometimes called *Aquafortis*. It is, when pure, a colourless, fuming, and remarkably corrosive acid. The commercial acid is yellow, arising from the presence of the lower oxides of nitrogen. It is obtained from a nitrate, as the nitrate of sodium or Potassium, by heating it with an *equal* weight of Sulphuric Acid.

$$KNO_3 + H_2SO_4 = HNO_3 + KHSO_4$$

When prepared on a *large* scale only *half* the weight of Sulphuric Acid is used. The following equations represent the reactions:

1st stage—$2KNO_3 + H_2SO_4 = KNO_3 + HNO_3 + KHSO_4$
2nd „ —$KNO_3 + KHSO_4 = HNO_3 + K_2SO_4$

This Acid is monobasic; it has a peculiar smell and a very sour taste; stains the skin yellow; freezes at —40°; is readily decomposed, and gives off a portion of its Oxygen to metals and combustible substances; phosphorus, charcoal, and sulphur, when heated with the acid, rapidly oxidise; when mixed with sulphuric acid and then poured on oil of turpentine, the mixture immediately takes fire; the acid acts most powerfully on metals when diluted to about 1.25; dissolves all the metals except gold, platinum, rhodium, and iridium; it forms with bases a great number of important salts which are all soluble in water; it has been obtained by passing electric sparks through moist air.

Second Hydrate of Nitric Acid.—Some chemists consider that there is a second hydrate having this composition.

$$2HNO_3, 3H_2O.$$

Tests.—Add solution of Sulphate of Iron, and afterwards Sulphuric Acid, to a solution containing Nitric Acid, or a nitrate, when a brownish red line is seen; heated with copper turnings it gives off red fumes.

Nitric Anhydride, or Anhydrous Nitric Acid. N_2O_5. Got from the Nitrate of Silver by passing dry Chlorine gas over it.

$$4AgNO_3 + 2Cl_2 = 4AgCl + O_2 + 2N_2O_5$$

Discovered in 1849, by M. Deville; it is a colourless crystalline body which melts at 85° and boils at 113° (F); dissolves in water, giving out much heat, and yielding the hydrated acid.

37. Nitrates.

Many Nitrates are anhydrous; some contain 3, 4, 5 or 6 atoms of water; no acid nitrates known, but several basic nitrates may be obtained; most are easily melted, and all are decomposed when strongly heated, as when thrown on the fire; *touch-paper* is got by dipping paper into the solution of any nitrate and then drying it.

Nitrate of Potassium	KNO_3.	Nitrate of Sodium	$NaNO_3$
„ Ammonium	H_4NNO_3.	„ Barium	$Ba2NO_3$
„ Strontium	$Sr2NO_3.5H_2O$.	„ Calcium	$Ca2NO_3.4H_2O$
„ Magnesium	$Mg2NO_3.6H_2O$.	„ Zinc	$Zn2NO_3.6H_2O$
„ Iron	$Fe2NO_3.6H_2O$.	„ Copper	$Cu2NO_3.6H_2O$
„ Lead	$Pb2NO_3$.	„ Silver	$AgNO_3$

Mercurous Nitrate ...... $HgNO_3 . H_2O$.
Basic Nitrate of Copper .. $Cu2NO_3, 3CuH_2O_2$.
Basic Nitrate of Lead... $Pb2NO_3, PbH_2O_2$.
Basic Mercurous Nitrate.... $3HgNO_3 . HgHO$.

38. Nitrous Oxide, or Protoxide of Nitrogen. N^2O. Mol. Vol., $\boxed{|}$; Sp. Gr., 1.527.—This is an invisible gas, having a faint agreeable smell and sweetish taste; 100 cu. in. of water at 32° (F.) dissolve 130 cu. in. of the gas, but at 75° (F.) only 60 cu. in., so that the gas should be collected over warm water; it supports combustion, which may be shown as with oxygen; reduced to a liquid by pressure of 50 atmospheres at 45° (F.); this liquid boils at—126°, and freezes at—150°; the gaseous protoxide is neutral; it is distinguished from oxygen by its solubility in water; it has an intoxicating effect when breathed, hence called *laughing gas*; 100 cu. in. weigh 47.29 grains; mixed with equal vol. of hydrogen and fired by electric spark in eudiometer, it explodes and sets free its own measure of nitrogen, and thus its composition is determined.

Preparation.—It is most readily obtained by heating the nitrate of ammonium in a retort or flask.

$$H_4NNO_3 = 2H_2O + N_2O.$$

39. Nitric Oxide, Deutoxide, or Binoxide of Nitrogen. NO. Atomic Vol., $\boxed{\backslash}$; Sp. Gr., 1.039.—This is a colourless and transparent gas; neither combustible nor supporter of combustion; if decomposed by heated phosphorus, the latter then burns brilliantly; irrespirable; neither acid nor alkaline; water only dissolves $\frac{1}{20}$th its bulk; has not been liquified; has unpleasant smell; consists of 1 vol. each of oxygen and nitrogen uncondensed; forms red fumes in contact with air or oxygen; passed into solution of ferrous sulphate forms a reddish brown liquid.

Preparation.—Obtained ordinarily from nitric acid by adding to it twice its measure of water, and then pouring it on copper turnings.

$$3Cu + 8HNO_3 = 3\,(Cu2NO_3) + 2NO + 4H_2O.$$

1oz. copper and 4ozs. acid yield about 420 cu. in. NO.

40. Nitrous Anhydride, Hyponitrous Acid, or Azotus Acid. N_2O_3.—As a vapour this is brownish red, but condensed at 0°(F.) it is a very volatile blue liquid; water in small quantity changes the colour of liquid to green, more water decomposes it into nitric acid and deutoxide of nitrogen; forms *Nitrites* with the Alkalies; these Nitrites commonly found in well-water of towns.

Preparation.—By mixing in an exhausted receiver 4 measures of nitric oxide with 1 measure of oxygen; this gives the anhydride as red fumes; condensed to 0° (F.) it is a blue liquid.

41. Peroxide of Nitrogen, Hyponitric Acid, or formerly **Nitrous Acid.** N_2O_4.—This is obtained as a red vapour by allowing nitric oxide to mix with air or oxygen; the vapour may be condensed by a freezing mixture, forming prismatic crystals; these will melt at 10° (F.) and yield at the usual temperature of the air an orange-coloured liquid. The vapour is suffocating; water gradually added to the liquid peroxide changes it to a yellow colour, then green, blue, and colourless successively; produces a red colour in a neutral solution of sulphocyanide of potassium.

Preparation.—It may also be prepared by applying a strong heat to the dry nitrate of lead, in a small retort.

$$2(Pb2\,NO_3) = 2\,PbO + 2N_2O_4 + O_2$$

42. Ammonia, Volatile Alkali, or Spirit of Hartshorn.

Sym., H^3N; Eq., 17; Sp. Gr., 0.59; Atom. and Mol. Vol., $\boxed{1}$

The name Ammonia is derived from the Temple of Jupiter, Ammon, in Lybia, near which sal ammoniac was at one time prepared. This gas is found to a small extent *free* in the atmosphere, being produced by the decomposition of animal matter and various processes of oxidation. It is remarkable for its pungent smell and strongly alkaline properties. It is commonly prepared from the chloride of ammonium or sal ammoniac, by adding to it an equal weight of quicklime, and gently heating the mixture in a flask.

$$CaO + 2H_4NCl = CaCl_2 + 2H_3N + H_2O.$$

1oz. of the chloride of ammonium yields about 380 cu. in. of ammonia.

This gas cannot be obtained by uniting hydrogen with nitrogen; it is transparent and colourless; water at 32° (F.) dissolves 1050 times, and at 59° (F.) 727 times its bulk; this property may be shown by inverting a jar containing it over water; 100 cu. in. weigh 18.26 grains; produced sometimes by deoxidation of nitric acid; does not support combustion, but is slightly combustible, if a jet of the gas be passed over the hot air from a burning argand lamp; it has a burning taste; destroys life if breathed undiluted; neutralizes acids, forming a great variety of salts; may be liquified at—40° or under pressure of its own atmosphere; its composition shown by passing electric sparks through a given volume; two measures thus become four measures, which may be shown to consist of 3 vols. hydrogen and 1 vol. nitrogen.

43. Solution of Ammonia, Hartshorn, or **Liquid Ammonia.**—Got by passing gaseous Ammonia into water, through a series of bottles; its strength is indicated by its density; the most concentrated has sp. gr.

of about 0.875; its value is best ascertained by finding the amount of acid it will neutralize, as shown by an *Alkalimeter*; the gas may be expelled by boiling the liquid, even at ordinary temperature the gas is given off; the solution has a burning taste, is colourless, very alkaline, and freezes at about—40°.

Tests.—A solution of lime, potash, or soda added to a solution of Ammonia, then heated, will cause the volatile alkali to escape, which may be known (1) by smell; (2) by changing red litmus paper to blue; and (3) by formation of white fumes of chloride of ammonium.

44. **Ammonium.** H_4N. This compound has never been isolated, but appears to exist in all the salts of ammonia. Nitrate of ammonium for instance, H_4NO, NO_3, contains besides ammonia, an atom of water which cannot be removed by heat, without entirely decomposing the salt.

45. Carbon.

Eq., 12; Sp. Gr., as Diamond, about 3.3, as Vapour (theoretical) 0.4146;
Atomic Vol., ◫

Carbon is found nearly pure in nature, as the diamond, and less so as black-lead, or graphite and coal. Combined with oxygen it occurs in the atmosphere and in the various natural carbonates. It also forms the solid part of plants and trees. It is obtained artificially as wood-charcoal, by burning wood in a closed retort, and as animal charcoal by burning bones in a similar manner.

Diamond.—This is the purest form of Carbon; most valuable when colourless; it is generally yellow or brown; hardest substance known; cut by using its own powder; used for cutting glass; non-conductor of electricity; has beautiful lustre; will burn in oxygen yielding carbonic acid; found in India and the Brazils.

Graphite, Plumbago, or Black-Lead.—Sp. Gr., 2.35 to 2.15; found in Cumberland, Ceylon and United States; in Cumberland met with in clay slate; good conductor of electricity; has a metallic appearance; generally contains quartz, iron, and manganese in small quantities; remains unaltered in the air, hence used for blacking grates, &c.; used to lubricate machinery and for making crucibles; extensively employed in making lead pencils, the best kind being made of pure Graphite; may be obtained pure by mixing common graphite with chlorate of potassium and heating with strong sulphuric ac., then drying and heating the produce to redness; "kish" found on melted iron, when cool, is graphite.

Wood Charcoal is another form of Carbon; prepared by burning wood in a retort or in a heap covered with earth; dry wood yields more charcoal than green; used for gunpowder, fuel, &c.; it is antiseptic; removes noxious gases from decomposing animal or vegetable matter; made from boxwood it will absorb 90 times its vol. of Ammonia; removes colour from liquid.

Bone Black, or **Animal Charcoal.**—Got by heating bones or other animal matter in a retort; decolorizes liquids more readily than wood-charcoal, hence most commonly employed in clarifying sugar, &c.; removes colour most perfectly when reduced to finest powder, and is slightly acid or neutral; the deodorising power of charcoal is thought by some to arise from the oxidation of its particles.

Coke and Lamp Black are Carbon; the former is obtained by burning coal in a retort, and the latter is the collected soot from the combustion of resin, tallow, oil, &c.

46. Carbonic Oxide, CO ; Eq., 28 ; Sp. Gr., 0.967 ; **Atomic and Mol. Vol.** $\boxed{\;\;|\;\;}$.—This is a colourless and inodorous gas ; has little smell ; burns with a blue flame ; has not been liquified ; highly poisonous, even mixed with a large proportion of air ; does not support combustion ; is neutral to test paper ; does not form salts with any acids ; slightly soluble in water ; potassium heated to 176° absorbs the gas, forming COK ; its composition shown by exploding 20 parts of CO with 20 of O in a eudiometer, which yields 20 parts of carbonic anhydride(CO_2) and 10 of oxygen; when shaken with a hydrochloric solution of the subchloride of copper, $Cu_2\,Cl_2$, it is gradually absorbed ; it unites with chlorine, forming *phosgene*, or chloro-carbonic acid ; considered a compound radicle, forming several organic substances.

Preparations.—1.—By heating to a red heat in a gun barrel, equal weights of ground chalk and iron or zinc filings.

$$CaCO_3 + Fe = CaO + FeO + CO.$$

2.—By heating half-an-ounce of yellow prussiate of potash with 4 to 5 ozs. oil of vitriol : this yields more than a gallon of pure gas.

$$K_4\ Fe\ C_6N_6 + 6\,H_2O + 6\ H_2\ SO_4 = 6\,CO + 2K_2\ SO_4 + Fe\ SO_4 + 3\,((H_4N)_2\ SO_4).$$

3.—By adding oil of vitriol to a formiate.

$$2Na\ CHO_2 + H_2SO_4 = 2\ CO + Na_2\ SO_4 + 2H_2O.$$

4.—By heating oxalic acid with 5 to 6 times its weight of oil of vitriol.

$$H_2\ C_2\ O_4 = H_2O + CO + CO_2.$$

Tests.—Burns with pale blue flame, producing carbonic anhydride ; not soluble in water, but is so in a hydrochloric solution of sub-chloride of copper.

47. Carbonic Anhydride, Carbonic Dioxide, or Carbonic Acid.

Sym., CO_2; Eq. 44; Sp. Gr., 1·529; Atomic and Mol. Vol. ◫.

This is a poisonous and heavy gas. It is *free* in the atmosphere, being exhaled by all animals, and given off in the combustion of coal, wood, &c., and in the various processes of decay. It is easily obtained by adding almost any acid to a carbonate of lime, soda, &c. The reaction is shown by this equation, when the carbonate of lime (chalk) and hydrochloric acid are used :—

$$Ca\,CO_3 + 2\,HCl = Ca\,Cl_2 + H_2\,O + CO_2\text{; or,}$$
$$Ca\,O,\,CO_2 + H\,Cl = Ca\,Cl + HO + CO_2.$$

This gas has a somewhat acid smell and taste; it is unaltered by heat; electricity decomposes it; cold water dissolves its own vol. of the gas; 100 cu. in. weigh 47.303 grs.; neither combustible nor a supporter of combustion; it is given off in the respiration of animals; if above 3 or 4 per cent. in the air it is rendered poisonous, hence the necessity for ventilation in rooms; escapes from fermenting bodies, volcanoes, and ordinary fires; is a feeble acid, reddening litmus only for a short time; forced into water by suitable apparatus in the manufacture of *soda-water*; found in most natural water, giving it an agreeable taste; issues from the earth in the Grotto del Cane at Naples; in the Upas Valley in Java, &c.; may be used for killing insects for preservation; supplies carbon to plants; used for extinguishing extensive fires in mines; liquified by a pressure of 28 atmospheres.

Liquid Carbonic Acid is without colour; does not mix with water, but readily unites with alcohol, ether, oil of turpentine, &c.; has Sp. Gr. of 0·838 at 32°; more expansible than air.

Solid Carbonic Acid may be got by allowing a stream of liquid carbonic anhydride to pass into the air; the solid acid melts at -70°; produces a sensation of burning when touched; readily freezes mercury.

Test.—Lime-water becomes milky when carbonic anhydride is passed into it.

48. Carbonates.

Generally di-basic; alkalies take up a second equivalent of carbonic acid; excepting carbonates of the alkalies, insoluble in water; all carbonates are dissolved by nitric acid giving off the carbonic acid; most of the carbonates are decomposed by continued ignition.

Carbonate of Potassium	$K_2\ CO_3.\ H_2\ O.$
Carbonate of Sodium	$Na_2\ CO_3.\ 10\ H_2\ O.$
Acid Carb. (bicarbonate) of Potassium	$K\ H\ CO_3.$
Acid Carb. (bicarbonate) of Sodium.	$Na\ H\ CO_3.$
Trona (sesquicarb. sodium)	$2\ Na_2\ CO_3,\ H_2CO_3.\ 3H_2O.$
Sesquicarb. of Ammonium	$2(H_4N)_2\ CO_3.\ CO_2.$
Carbonate of Barium	$Ba\ CO_3.$
Carbonate of Calcium	$Ca\ CO_2.$
Carbonate of Magnesium	$Mg\ CO_3.$
Dolomite	$Mg\ Ca\ 2CO_3.$
Baryto Calcite	$Ba\ Ca\ 2CO_3.$
Malachite	$Cu\ CO_3,\ Cu\ H_2\ O_2.$
Blue Carbonate of Copper	$2Cu\ CO_3,\ Cu\ H_2\ O_2.$

49. Light Carburetted Hydrogen, Marsh Gas, Methyl Hydride, Subcarburetted Hydrogen, or Fire-Damp.

Sym., CH_4; Mol. Vol., $\boxed{\;\mid\;}$.; Sp. Gr., 0·5576; Eq., 16.

This is an inodorous, colourless, and tasteless gas, which escapes naturally in coal mines. It is known by miners as *fire-damp*. It explodes violently when a light is applied to a mixture of it with 8 or 10 times its bulk of air, or twice its bulk of oxygen. It may be prepared by heating in a flask coated with fire-clay, $10\frac{2}{3}$ hydrate of barium, and $10\frac{1}{3}$ anhydrous acetate of sodium.

$$2\ Na\ C_2\ H^3\ O^2 + BaO,\ H^2O = Ba\ CO^3 + Na^2\ CO^3 + 2\ CH^4.$$

This gas is a neutral body; does not form compounds with acids or bases; burns with a yellow flame, but does not support combustion; may be decomposed by electric sparks, or by passing it through heated tubes; forms with olefiant gas the most important portion of coal gas; not poisonous; 100 cu. in. weigh 17·41 grains; chlorine mixed with it produces no change in the dark, but in the light with moisture they yield carbonic anhydride and hydrochloric acid; the composition is shewn by burning a portion of the gas with twice its volume of oxygen, which yields one volume of carbonic anhydride and a small quantity of water; requires a white heat to inflame it; does not explode with less than 4 times or more than 16 times its volume of air. The explosion of this gas in coal mines occasions great loss of life. The **Davy Lamp** is designed to prevent such explosions; it consists of an oil lamp surrounded by wire gauze, having from 600 to 800 openings in the square inch. The gauze of the lamp prevents the flame from igniting the explosive mixture of air and marsh gas outside the lamp.

Other Preparations.—2. May be collected from stagnant water by inverting a jar and stirring the water.

3. Obtained from coal by destructive distillation.

Tests.—Burns with yellowish flame; not dissolved by fuming sulphuric acid; not acted on when mixed with chlorine over water, if light is excluded.

50. Olefiant Gas, Heavy Carburetted Hydrogen, Ethylene or Elayl.

Sym., C_2H_4; Sp. Gr., 0·9784; Mol. Vol., $\boxed{\ \vert\ }$; Eq., 28.

This is a gas which burns with a bright flame, and hence forms an important constituent of *coal gas*. It has no colour, but a faint ethereal smell. It is given off abundantly with other gases when coal is distilled. It is obtained tolerably pure on a small scale by heating in a large flask, a mixture of 2 measures of strong oil of vitriol with 1 measure of alcohol.

$$\begin{array}{ccccccc} \text{Alcohol.} & & \text{Oil of Vitriol.} & & \text{Ethylsulphuric Acid.} & & \text{Water.} \\ C_2H_6O & + & H_2SO_4 & = & HC_2H_5SO_4 & + & H_2O. \end{array}$$

Then by heat—

$$H C_2 H_5 SO_4 = H_2 SO_4 + C_2 H_4.$$

This gas is soluble in 12 times its volume of cold water ; it does not support combustion or respiration ; has been liquified by pressure of 40 atmospheres ; has not been solidified ; a red heat or electricity decomposes it, yielding carbon and light carburetted hydrogen ; explodes powerfully if mixed with three times its volume of oxygen, and lighted ; the composition of the gas is thus shewn ; mixed with an equal volume of chlorine it forms a liquid having a sweetish taste and oily appearance, and known as Dutch Liquid.

Liquid Olefiant Gas is colourless, and dissolves oils, resins, &c.

Tests.—Forms with chlorine, Dutch Liquid ; absorbed by nordhausen acid ; burns with bright flame.

51. Dutch Liquid ($C_4 H_3 Cl, H Cl$) or $C_2 H_4 Cl_2$.

Eq., 99 ; Sp. Gr., 1·28 at 32° ; Com. Vol., $\boxed{1}$.

This liquid has an agreeable smell ; colourless ; not soluble in water, but readily so in ether and alcohol ; boils at 180° ; burns with a greenish light.

52. Manufacture of Coal Gas.

Coal gas consists chiefly of Heavy and Light Carburetted Hydrogen ; it also contains Hydrogen, Carbonic Oxide, Nitrogen, Carbonic Acid, Sulphuretted Hydrogen, and Ammonia, all of which, excepting hydrogen, are impurities, and are to a great extent removed. In its manufacture, Lancashire *cannel*, Scotch *parrot*, or Newcastle coal are most used. One ton of the last-named yields 9250 cu. ft. of gas, having Sp. Gr. 0·410. The coal is distilled in iron or clay retorts ; from these the gas and tarry vapour are conducted into the *hydraulic main*, and thence to the *condensers*, depositing in both, tar, ammonia, water, &c. After this the gas is purified by passing through layers of lime or oxide of iron and sawdust, removing carbonic acid, sulphuretted hydrogen, cyanogen, &c. Ammonia is lastly removed by conducting the gas through oil of vitriol. Instead of the last process, a *scrubber* is sometimes used, by which the gas is washed in passing through a tower of stones within a cylinder. The gas is stored in *gasometers;* the tar is collected from the condensers in wells. Aniline colours and naphtha are obtained from the tar, and sal ammoniac from the *ammoniacal liquor*. The illuminating power of coal gas is generally determined by burning a sperm candle at the rate of 120 grains a minute, and 5 cubic feet of gas per hour, then comparing the results. Gas, for instance, from cannel, is about equal to 34, and from coal to 13 candles.

53. Combustion.

Bodies are said to be in a state of *combustion*, when, in consequence of rapid chemical action, *light* and *heat* are given off. When a candle is burnt, the hydro-carbons of the wax or tallow are rapidly united with the oxygen of the air, to support the flame. The flame of a candle contains three *zones:*—1st, the dark zone or area around the wick, where the gas is unburnt; 2nd, the bright zone surrounding the former, where the gas is partially consumed; and 3rd, the zone of complete combustion, which is outside that. The flame produced by a *blowpipe* contains two zones or areas—the outer or *oxidizing* flame, and the inner or *reducing* flame. Many substances, as for instance charcoal, when finely divided, absorb and condense the air within their pores, producing oxidation and increase of temperature, which if continued, results in *Spontaneous Combustion.* Spongy platinum possesses this power in a high degree. Phosphorus exposed to air slowly oxidises, furnishing an example of *Slow Combustion.* Oxygen, nitrous oxide, &c. are called *supporters of combustion,* because other bodies will burn in an atmosphere of these gases. In the *Bunsen's gas-flame,* the gas is completely burnt by allowing air to mix with it through small openings at the bottom of the burner.

54. Chlorine.

Sym., Cl; Eq., 35·5; Sp. Gr., 2·47; Atom. Vol., □.

This is a heavy and greenish-yellow gas. It has a very suffocating smell, and produces considerable irritation of the air passages, even when greatly diluted with air. It may be condensed to a yellow liquid by a pressure of 4 atmospheres at 60° (F). Water absorbs twice its bulk of this gas. It is extensively used for bleaching, and as a disinfectant. The gas is found very abundantly in nature combined with sodium, forming common salt, or chloride of sodium. It is commonly obtained from hydrochloric acid, by heating it with oxide of manganese.

$$\mathrm{Mn\,O_2} + \mathrm{4H\,Cl} = \mathrm{Mn\,Cl_2} + \mathrm{2H_2O} + \mathrm{Cl_2}.$$

Half a pint of acid diluted with 3 ozs. of water, and added to 3 ozs. of manganese, yields over 3 gallons of gas.

Second Method of Preparation.—Four parts common salt are well mixed with 3 parts oxide of Manganese; then 10½ parts sulphuric acid are added, being diluted with 7 parts of water. The gas escapes freely on applying a gentle heat.

$$\mathrm{Mn\,O_2} + \mathrm{2\,Na\,Cl} + \mathrm{3H_2\,SO_4} = \mathrm{Mn\,SO_4} + \mathrm{2\,Na\,H\,SO_4} + \mathrm{2H_2O} + \mathrm{Cl_2}.$$

This gas enters largely into the composition of many minerals, and occurs with other substances in sea-water; 100 cu. in. weigh over 77 grains. The gas does not conduct electricity; it acts powerfully on mercury; forms with water a definite hydrate ($Cl + 5H^2O$). The hydrate crystallises at 32°. The gas is not combustible. Phosphorus, powdered antimony, and arsenic, with bodies rich in hydrogen, as ammonia and oil of turpentine, burn spontaneously in the gas. Breathed in small quantities, it produces sneezing and coughing; if inhaled pure, causes immediate death; combines with hydrogen of vegetable colours, and thus destroys them, hence the use of the gas in bleaching. If water is present with Chlorine, colour is thought by some to be removed, by the hydrogen uniting with Cl. and setting free the oxygen to act on colouring matter. A powerful disinfectant.

Uses.—Bleaching cotton, linen, &c.; as a disinfectant; in preparation of chlorate of potassium and red prussiate of potassium.

Tests.—Peculiar smell and bleaching properties; white precipitate with nitrate of silver.

55. Chlorides.

Chlorine unites with all other elements forming Chlorides; all except chlorides of silver and subchlorides of mercury and copper are soluble in water. Chlorine, like oxygen, sometimes unites with the same metal in two or more proportions, as platinous and platinic chlorides.

Chloride of Potassium	KCl.	Chloride of Sodium.	$Na\ Cl$.
„ Ammonium	H_4NCl.	„ Barium	$Ba\ Cl_2,\ 2H_2O$.
„ Strontium.	$SrCl_26H_2O$.	„ Calcium	$Ca\ Cl_2,\ 6H_2O$
„ Magnesium	$MgCl_26H_2O$.	„ Aluminum.	$Al_2\ Cl_6$.
Chromous Chloride	$Cr\ Cl_2$.	Manganous Chloride	$Mn\ Cl_2\ 4H_2O$.
Chromic Chloride	$Cr^2\ Cl_6$.	Manganic Chloride	$Mn_2\ Cl_6$.
Oxychloride of Manganese	$Mn_2\ Cl_7$.	Chloride of Nickel	$Ni\ Cl_2$.
Ferrous Chloride	$Fe\ Cl_2$.	„ Cobalt	$Co\ Cl_2$.
Perchloride of Iron.	$Fe_2\ Cl_6$.	„ Zinc	$Zn\ Cl_2$.
Cupreous Chloride	$Cu_2\ Cl_2$.	Terchloride of Antimony	$Sb\ Cl_3$.
Cupric „	$Cu\ Cl_2$.	Pentachloride „	$Sb\ Cl_5$.
Terchloride of Bismuth	$Bi\ Cl_3$.	Chloride of Gold	$Au\ Cl$.
Stannous Chloride	$Sn\ Cl^2$.	Ter or Trichloride of Gold,	$Au\ Cl_3$.
Stannic „	$Sn\ Cl_4$.	Chloride of Silver	$Ag\ Cl$.

Mercurous Chloride, or Calomel, $Hg\ Cl$.

Mercuric Chloride, or Corrosive Sublimate, $Hg\ Cl_2$.

Platinous Chloride, $Pt\ Cl^2$. Platinic, or Tetrachloride, $Pt\ Cl_4$.

56. Hydrochloric or Muriatic Acid.

Sym., HCl; Eq., 36·5; Sp. Gr., 1·247; Atom. and Mol. Vol., ◫.

This is a colourless gas, which forms dense fumes in damp air. It is neither combustible nor a supporter of combustion. It does not bleach, but reddens vegetable blues. It may be liquified by a pressure of 40 atmospheres at 50°, yielding a colourless liquid. It may be obtained by exposing to sunlight equal volumes of chlorine and hydrogen. It is, however, more readily prepared by heating common salt and sulphuric acid in a flask.

$$NaCl + H_2SO_4 = HCl + NaHSO_4.$$

It must be collected over mercury or by displacement.

57. Solution of Hydrochloric Acid.

When gaseous hydrochloric acid is passed into water at 40°, the water absorbs 480 times its bulk of the gas. A solution of the gas thus obtained is called *Hydrochloric Acid*, *Muriatic Acid*, or *Spirit of Salt*. The commercial acid generally contains a variety of impurities, as chlorine, sulphur, chloride of iron, &c. When quite pure, it is colourless. It fumes in the air, and the gas is rapidly given off when the liquid is heated. The strongest acid has a Sp. Gr. of 1·203, and contains 1 atom of real acid to 6 atoms of water. It freezes at —60°, and boils at 112° (F). It is an irritant poison, and its vapours are injurious to vegetation. The acid is a waste product in the manufacture of carbonate of sodium.

The following equations will illustrate the action of this acid upon metals :—

With *hydrate* of soda, a *monoequivalent* :

$$Na\,HO + H\,Cl = Na\,Cl + H_2O.$$

With Baryta, a *biequivalent* :

$$Ba\,O + 2H\,Cl = Ba\,Cl_2 + H_2O.$$

With Sesquioxide of Iron :

$$6H\,Cl + Fe_2\,O_3 = 3H_2O + Fe_2\,Cl_6.$$

With Binoxide of Manganese :

$$Mn\,O_2 + 4H\,Cl = Mn\,Cl_2 + 2H_2O + Cl_2.$$

Uses.—Used in manufacture of bleaching powder and of glue ; also for preparation of chlorides, and of obtaining solutions of metals.

Test.—Gives a white curdy pp. with nitrate of silver.

58. Aqua Regia, Nitro-Muriatic Acid, or Nitro-Hydrochloric Acid.—This is obtained by mixing 3 parts of hydrochloric acid with 1 of nitric acid. These acids decompose each other, and yield first, free chlorine, and ruddy fumes known as *chloro-nitric gas* ($NO\,Cl^2$), and afterwards *chloro-nitrous gas* ($NO\,Cl$), which is of a deep orange-red colour. When aqua regia is used as a solvent, the *nascent* chlorine dissolves the metal, and combines with it. The following equation illustrates the reaction :—

$$6M + N_2\,O_5 + 6H\,Cl = 6M\,Cl + N_2\,O_2 + 3H_2\,O.$$

59. Hypochlorous Anhydride, or Hypochlorous Oxide. Sym., Cl_2O ; Sp. Gr. 2·977 ; Mol. Vol. ◫.—This is a yellow gas, having a very strong and penetrating smell ; water absorbs 200 times its volume of the gas, forming *hypochlorous acid* ($H\,ClO$) ; the solution has odour of the gas, and powerful bleaching properties. The gas explodes in contact with combustible bodies, yielding two vols. of chlorine and one of oxygen. As a bleacher more effective than chlorine ; may be condensed to red liquid, which boils at 19° by passing the gas into a U tube at -4° temperature ; with bases forms Hypochlorites. The gas is prepared by passing dry chlorine through a tube containing well-dried oxide of mercury. The gas may be condensed as it is produced, by surrounding the receiver with a freezing mixture.

$$HgO + 2Cl_2 = Hg\,Cl_2 + Cl_2O.$$

60. **Hypochlorous Acid** (H ClO); Eq., 52·5.—This may be obtained by shaking 1 part red oxide of mercury with 12 parts water, in a large bottle of chlorine.

$$H_2O + 3\ Hg\ O + 2\ Cl_2 = 2HgO,\ HgCl_2 + 2HClO.$$

This acid, combined with lime, forms the important *bleaching agent*, Chloride of Lime.

61. Bleaching.

Calico and some other fabrics are bleached by the use of the Chloride of Lime. This compound is prepared by passing chlorine gas through layers of moistened lime on perforated shelves. This is supposed to be the reaction :—

$$2\ Ca\ H_2O_2 + 2\ Cl_2 = 2\ H_2\ O + Ca\ Cl_2 + Ca\ 2\ ClO.$$

The following are the processes in bleaching cotton :—1, Boiling, *bucking*, or *bowking*, with milk of lime. 2, Washing with water. 3, *Souring* in hydrochloric acid, removing lime soaps formed by first operation. 4, Washing to remove excess of acid. 5, *Bucking* with solution of soda-ash and resin. 6, Washing and immersing in chlorine-bath, or *chemicking*. 7, Souring in hydrochloric or sulphuric acid. The chloride of lime which adheres to the fabric in the 6th operation is decomposed by the acid in the 7th process, which sets free the chlorine to act on the fibres of the cloth.

62. **Chlorous Anhydride**, Cl_2O_3; Sp. Gr., 2·646; Mol. Vol., ☐☐☐.—This is a gas of a dark yellowish green colour; has a penetrating smell; powerful bleacher; may be condensed to a red liquid; water dissolves six times its volume, forming a yellow solution; explodes when heated to 135°, and is decomposed into chlorine and oxygen; carbonic anhydride expels it from its compounds. It is prepared by deoxidising Chloric Acid with Arsenious Acid; 3 parts Arsenious Acid are made into a paste with 4 parts of Chlorate of Potassium and Water; 16 parts Nitric Acid are added; gentle heat applied; collected by displacement.

$$H_3\ As\ O_3 + H\ NO^3 = H_3\ As\ O_4 + H\ NO_2,\ \text{then}$$
$$2H\ NO^2 + 2\ K\ Cl\ O_3 = 2K\ NO_3 + Cl^2O^3 + H_2O.$$

63. Chlorous Acid ($HClO_2$) has bleaching properties; it forms Monobasic Salts called *Chlorites.*

64. Peroxide of Chlorine, ClO_2; Sp. Gr. 2·322; Mol. Vol. $\boxed{1}$.—This is a yellow gas; slightly aromatic smell; water dissolves about 20 times its bulk of the gas; the solution bleaches readily; reduced to red liquid at —4°; light, heat, or electricity easily decomposes the gas; explodes in contact with sulphur or phosphorus; this may be shewn by placing a few grains of chlorate of potassium and a little phosphorus at the bottom of a test glass, then covering with water and pouring through a tube, oil of vitriol. To prepare it, chlorate of potassium with two-thirds its weight of oil of vitriol, are made into a paste, and gently heated.

$$3K\,Cl\,O_3 + 2H_2\,SO_4 = 2Cl\,O_2 + K\,Cl\,O_4 + 2KH\,SO_4 + H_2O.$$

65. Chloric Acid, or Hydric Chlorate ($H\,Cl\,O^3$).—Has not been obtained anhydrous; the concentrated solution is very acid; has an oily appearance and strong smell; paper ignites when put into it; decomposed above 104°; not decomposed by light. This acid is obtained by passing a current of chlorine through a solution of caustic potash.

$$3Cl_2 + 6K\,HO = 5K\,Cl + K\,Cl\,O^3 + 3\,H^2\,O.$$

The acid is afterwards set free by adding hydrofluosilicic acid to the chlorate of potassium.

$$2K\,Cl\,O^3 + H_2\,Si\,F_6 = 2H\,Cl\,O_3 + K_2\,Si\,F_6.$$

Tests.—Solution of chlorate, coloured with sulphuric acid solution of indigo, then sulphuric acid, and a few drops of sulphite of soda added, the blue colour disappears. By heating chlorates with hydrochloric acid, *Euchlorine* is given off—a greenish yellow gas.

66. Chlorates.

Chlorates are decomposed by concentrated sulphuric acid, and chlorine and oxygen are given off; a grain or two of chlorate of potassium with the same weight of sugar takes fire on adding oil of vitriol; they are soluble in water; decomposed by heat; produce scintillation when thrown on fire.

Chlorate of Potassium. $K\,Cl\,O_3$
" Barium, $Ba\,ClO_3$
" Cobalt, $Co\,ClO_3 + 3H_2\,O$.
" Lead, $2Pb\,ClO_3 + H_2\,O$.
" Silver, $Ag\,ClO_3$
" Strontium, $Sr\,ClO_3$
" Magnesium, $Mg\,ClO_3 + 3H_2\,O$.

Chlorate of Calcium, $Ca\,ClO_3 + H_2\,O$.
" Nickel, $Ni\,ClO_3 + 3H_2\,O$.
" Copper, $Cu\,ClO_3 + 3H_2\,O$.
" Lithium, $2Li\,ClO_3 + H_2\,O$.
" Sodium, $Na\,ClO_3$
" Zinc, $Zn\,ClO_3 + 3H_2\,O$.

67. Perchloric Acid or Hydric Perchlorate, $HClO_4$; Sp. Gr. of liquid 1.782. This is a colourless liquid; it remains liquid at —31°; it is one of the most powerful oxidising agents known; when concentrated it fumes in the air; has an oily appearance; boils at 392°; distilled carefully with Sulphuric Acid, a portion of the Acid distils over, forming crystals; has not bleaching properties; has strong affinity for bases. The Perchlorates are all soluble; all are decomposed by heat, giving off Oxygen; they explode when thrown on burning charcoal. This liquid is prepared by expelling one-third oxygen from chlorate of potassium by heating it; perchlorate of potassium is formed and separated from undecomposed chlorate, by adding hydrochloric acid; one part perchlorate is afterwards distilled with four parts oil of vitriol.

$$2KClO_3 = KClO_2 + KClO_4$$

68. Chloride of Nitrogen. Sym. HCl_2N, Cl_3N? Sp. Gr. of Liquid 1.653. This is an oily, yellow liquid; volatilises rapidly in air; penetrating odour; explodes when heated to between 200° and 212°, or when brought in contact, at common temperature, with fats, fatty oils, phosphorus, and the alkalies; does not explode with resins, strong acids, metallic bodies, or sugar; one of the most dangerous compounds known. It may be prepared (1) by suspending a small piece of sal ammoniac in hypochlorous acid or; (2) by inverting a jar of chlorine, free from grease, over a solution of sal ammoniac or; (3) by passing gaseous ammonia into a jar of chlorine.

69. Acetylene Chloride of Carbon.—C_2Cl_2. Obtained from ethylene-chloride by passing it several times through a red-hot tube. It forms silky crystals, is soluble in ether, and burns in air with red smoky flame.

70. Ethylene Chloride of Carbon—C_2Cl_4; Sp. Gr. of Liquid 1.5; of Vapour 5.8; Mol. Vol. ☐☐. This is a colourless liquid, having a pleasant smell; is obtained from Faraday's chloride by subliming it repeatedly through a tube, containing pieces of glass, and heated to redness.

71. Faraday's Chloride of Carbon—C_2Cl_6; Sp. Gr., of Solid 2.0; of Vapour 8.15; Mol. Vol. ☐☐. A solid crystalline substance, having a smell of camphor; it dissolves in ether, alcohol, and in the fixed and volatile oils. It may be obtained by acting upon Dutch liquid with chlorine, exposed to the sun's rays; boiling point, 360°.

72. Tetrachloride of Carbon CCl_4; Sp. Gr. of Liquid 1.59; of Vapour 5.3; Mol. Vol. ☐☐. This is a liquid without colour and insoluble in water, but soluble in alcohol and ether; at —9° it becomes a crystalline solid; boils at 172°. Obtained by passing a mixture of chlorine and bisulphide of carbon through a red-hot porcelain tube. May also be got by the action of excess of chlorine upon chloroform.

73. **Oxychloride of Carbon, Chlorocarbonic Acid** or **Phosgene Gas**, $CO\,Cl_2$; Sp. Gr. 3.68; Mol. Vol. ◫. This is a suffocating gas, which is got by exposing to the sun's rays equal volumes of carbonic oxide and chlorine. These gases combine and are condensed into half their volume.

74. Bromine.

Br. = 80; Sp. Gr., 5.54 (of Vapour), 3.187 (of Liquid at 32°).
Atom. Vol. of Vapour □.

This is a heavy and brownish-red liquid. It is remarkably volatile, giving off a dense red vapour similar to peroxide of nitrogen in appearance. It has a similar smell to chlorine, and when inhaled is very poisonous. It bleaches many colours. It was discovered by Balard in 1826. It is obtained from some saline springs, but generally from sea water, which contains from one-third of a grain to one grain of Bromide of Magnesium per gallon. After all the crystallizable salts are removed, chlorine is passed through the mother liquor, which decomposes the Bromide.

$$Mg\,Br_2 + Cl_2 = Mg\,Cl_2 + Br_2$$

Ether is added to the solution which takes up the Bromine, and the ethereal solution is decanted and shaken with solution of potash.

$$3Br_2 + 6K\,HO = K\,BrO_3 + 5K\,Br + 3H_2\,O.$$

The liquid is evaporated to dryness, and the solid bromate is then decomposed by ignition, and afterwards distilled with binoxide of manganese and oil of vitriol.

$$2K\,Br + MnO_2 + 2H_2\,SO_4 = K_2\,SO_4 + MnSO_4 + 2H_2\,O + Br_2$$

This liquid dissolves readily in alcohol and ether, and slightly in water; produces sores when dropped on the hand; when swallowed is a powerful poison; the vapour irritates the nose; forms with water a hydrate ($Br. 5H_2 O$); becomes a yellowish-brown and brittle solid at 9°.5; forms *Bromides* with the metals; boils at 145°.4 F.

Tests.—With nitrate of silver a yellowish white precipitate is given by solutions of Bromides or Hydrobromic Acid; the pp. is insoluble in cold nitric acid, and nearly so in ammonia. A yellow colour is given with nitric acid and starch paste.

Bromides.—They are all solid at ordinary temperature; are for most part fused at a moderate heat; generally soluble in water; all decomposed by chlorine; yield red vapours of bromine when heated with black oxide of manganese and oil of vitriol.

75. **Bromic Acid** ($H\,Br\,O_3$).—This acid is similar in composition to chloric acid. It is prepared from the bromate of potassium, in the same manner as chloric acid is prepared (par. 65). Bromate of potassium is got by acting on a solution of caustic potash by bromine. This acid reddens litmus, and afterwards destroys the colour; all the known salts are monobasic.

76. **Bromates**, when heated to redness, either give off their oxygen and leave *bromides*, or they give off bromine and part of their oxygen, and leave oxides; many of them are decomposed when their solutions are heated; solid bromates heated with sulphuric acid give off bromine and oxygen.

77. **Hydrobromic Acid, Bromide of Hydrogen, or Bromhydric Acid**, H Br; Sp. Gr., 2·73; Mol. Vol., ◫.—This is a colourless, pungent, and acid gas; is not inflammable; extinguishes flame; irritates the lungs; has been liquified at -92°, and solidified at -100°; is very soluble in water; the solution having Sp. Gr. of 1·486 contains 47 per cent. anhydrous acid; acts like HCl upon metallic oxides, forming bromides of the metals.

$$\text{Ex.—}K\,HO + HBr = KBr + H_2\,O.$$

This acid may be prepared (1) by the action of water on tribromide of phosphorus:—

$$PBr_3 + 3H_2O = H_3\,PO_3 + 3HBr.$$

2. By decomposing bromide of sodium or potassium with strong sulphuric acid.

$$2\,Na\,Br + H_2\,SO_4 = Na_2\,SO_4 + 2H\,Br.$$

78. Iodine.

Sym., I = 127 ; Sp. Gr., Vapour 8·716, of Solid 4·947. Atom. Vol. □; Melting Point, 225° ; Boiling Point, 347°.

This element exists in small quantities in sea-water. It is obtained from *Kelp*, the ash of marine plants which have absorbed it. The ash is dissolved by pouring on it boiling water ; the solution is then evaporated when the carbonate and sulphate of sodium, chloride of potassium, &c. are separated by crystallization ; one-eighth by measure of oil of vitriol is now added, and the liquid stands for 24 hours. Carbonic anhydride, sulphuretted hydrogen, and sulphurous anhydride escape, whilst sulphate of sodium crystallizes. The liquid is afterwards distilled in a leaden retort with oxide of manganese :—

$$2NaI + MnO_2 + 2H_2SO_4 = Na_2SO_4 + MnSO_4 + 2H_2O + I_2.$$

By this process iodine is furnished as bluish-black scales, like black-lead. It stains the skin yellow. When heated it gives off a dense purple vapour. In large doses it is a strong poison.

Iodine as crystals is octohedron with rhombic base ; is a non-conductor of electricity ; volatile at ordinary temperature giving off smell of chlorine; it is soft and brittle ; in small quantities a very useful medicine for swellings of the glands ; has an acrid taste ; fuses at 224°.6, and boils at 347°, forming a beautiful purple vapour ; dissolves very slightly in water; is dissolved freely in alcohol, ether, &c. ; unites readily with metals forming iodides.

Test.—Iodine gives a deep blue colour with starch, and stains the skin yellow.

79. Iodides.—The Iodides are decomposed by chlorine, bromine, nitrous acid, and strong nitric acid setting free iodine ; they are in general readily dissolved by water ; the biniodide of mercury, having a bright scarlet colour, is obtained by adding corrosive sublimate to a solution of an iodide ; most iodides, when heated in air, are oxidised.

80. **Iodic Anhydride, I_2O_5.**—This is got by heating Iodic Acid.

81. **Iodic Acid, HIO_3.**—This is a white crystalline body; is very soluble in water, and slightly so in alcohol; the hydrate yields the anhydride when heated to 338°; when melted is reduced to oxygen and iodine; heated to 700° with combustible bodies, it gives up its oxygen; is decomposed by sulphuretted hydrogen, hydrochloric acid, &c.; forms crystalline compounds with nitric and sulphuric acids; its solution has a sour and astringent taste; the *Iodates* contain one, two, or three atoms of acid to one of base; are decomposed into Iodides by application of heat. The acid is prepared generally by suspending 1 or 2 ounces of powdered iodine in a pound of water; chlorine is then passed into the water until the iodine dissolves:—

$$6H_2O + 5Cl_2 + I_2 = 10\,HCl + 2HIO_3.$$

Carbonate of sodium is now added, and the terchloride of iodine is formed, hence:—

$$5I\,Cl_3 + 9\,Na_2\,CO_3 = 15\,Na\,Cl + 3\,Na\,IO_3 + I_2 + 9\,CO_2.$$

By adding chloride of barium, the iodate of barium is obtained, and this is decomposed by sulphuric acid.

Test.—The acid is set free by sulphurous acid.

82. **Periodic Acid, HIO_4.**—This is prepared in the form of colourless crystals, which dissolve quickly in moist air; the crystals contain two atoms of water ($H\,IO_4\;2H_2O$); by application of heat the water is given off, leaving periodic anhydride; the acid dissolves easily in water, but sparingly in alcohol and ether; it gives a precipitate with nitrate of silver; it is decomposed by sulphuretted hydrogen. This compound is prepared by passing chlorine through a solution of 3 equivalents of caustic soda and 1 equivalent iodate of sodium:—

$$2\,Na\,IO_3 + 6\,Na\,HO + 2\,Cl_2 = Na_2\,O,\,2\,Na\,IO_4 + 4\,Na\,Cl + 3H_2\,O.$$

The Periodate of Soda, thus obtained, is dissolved in nitric acid and pp. by nitrate of silver, giving periodate of silver. This salt is decomposed by water into insoluble basic periodate of silver and free periodic acid in solution. **The Periodates** generally are but slightly soluble in water, but dissolve readily in dilute nitric acid.

83. **Hydriodic Acid, HI.** Sp. Gr., 4·443; Mol. Vol., $\boxed{1}$.—This as a gas is acid, colourless, and suffocating, resembling HCl; neither combustible nor supports combustion; fumes in the air; by strong pressure reduced to yellow liquid, which solidifies at —60°; water dissolves the gas freely; a solution is obtained by passing sulphuretted hydrogen through water containing iodine.

$$2H_2 S + 2I_2 = 4HI + S_2.$$

The strongest solution boils at about 260°; has a Sp. Gr. of 1·7; and contains $2\ HI + 11\ H_2O$; it dissolves iodine; gaseous hydriodic acid is decomposed by chlorine and bromine, also by passing it with oxygen through a red-hot tube; mercury slowly decomposes it; composition similar to HCl, containing 1 vol. iodine, with 1 vol. hydrogen uncondensed. To prepare it, ten parts of iodide of potassium, and five of water, are added to 20 of iodine; one part phosphorus is then gradually dropped in, and heat applied.

$$8\ KI + 10\ I_2 + P_4 + 16\ H_2\ O = 4\ K_2\ H\ PO_4 + 28\ HI.$$

84. Iodide of Nitrogen, NHI_2 This is a black powder obtained by placing for half an hour finely-powdered iodine in a solution of ammonia. This is a dangerously explosive body; friction under water will cause it to explode; sulphuretted hydrogen decomposes it.

85. Fluorine.

$F = 19$. Theoret. Density 1.31; Com. Vol., □.

This element has not yet been satisfactorily isolated. The following method is said to yield it:—A thin and small glass cylinder containing dry fluoride of silver is placed in a tube containing iodine; the iodine is heated to expel air; the tube is then hermetically sealed, and heated for 24 hours to about 180°. This gives a colourless gas, which does not attack glass, and which caustic potash absorbs, forming fluoride of potassium.

$$2K\ HO + F_2 = 2K\ F + H_2\ O_2$$

Fluorine combined with calcium forms the mineral *fluorspar*, and with sodium and aluminum *cryolite* ($3Na\ F,\ Al\ F_3$), a mineral met with in Greenland.

86. Hydrofluoric Acid.

$HF = 20$; Sp. Gr., *Anhydrous Vapour*, 0.689; Atom. Vol. □□.

This is a gas, and may be got by the action of sulphuric acid on *fluorspar* (fluoride of calcium), in a leaden saucer.

$$H_2\ SO_4 + Ca\ F_2 = 2HF + Ca\ SO_4$$

The gas may be condensed by passing it into a tube surrounded by a freezing mixture of —4°. This liquid boils at 60°. It acts powerfully on the skin, producing a painful burn. It occasions a hissing sound when thrown on water. When diluted it dissolves the metals, excepting mercury, lead, platinum, gold, and silver. It has never been frozen. It readily attacks silicon in glass, forming the fluoride of silicon, hence its use in *glass etching.*

Use.—The liquid acid mixed with six parts of water used for etching glass.

Test.—Its action on glass.

87. **Fluorides** generally fuse when heated, and hence the name *fluoride*, from *fluo*, to flow ; all are decomposed when heated with oil of vitroil; a large number are insoluble in water, and others only slightly so; glass vessels are corroded by solutions of the fluorides; nitrate of silver gives no pp. with them.

88. Sulphur or Brimstone.

S = 32. Sp. Gr., Solid, 1.98, Vapour 6.617 at 900°, and at 1900° 2.2; Com. Vol. below 1500° ⅓, at 1900°, □.

This is a greenish-yellow substance, met with chiefly in volcanic districts. It is also found combined with many metals forming the *sulphides* of the metals. It occurs, too, in the native *sulphates* of barium, lime, magnesium, &c. It is usually sold as a powder (Flowers of Sulphur), or in sticks (Roll Sulphur). It is very inflammable, and burns with a blue flame.

Preparation.—The sulphur used in England for most part is brought from Sicily ; found abundantly with iron, lead, silver, and zinc, forming sulphides of those metals ; found with hydrogen in Harrogate and other waters, and is present in plants and animals. In Sicily, sulphur is extracted from the ore by distillation ; earthenware retorts holding 4 to 5 gallons are filled with the ore ; these are placed in a long brick furnace ; the sulphur rises as a vapour, and passes through an opening at the top of the retort into a corresponding retort outside the furnace, and from that into a vessel of water; when sulphur is re-distilled, and the vapour passed into a cold chamber, "Flowers of Sulphur" are formed. When the chamber is heated and the melted sulphur run into cylindrical vessels, "Roll Sulphur" is obtained. Sulphur is sometimes got from iron pyrites, (FeS_2.); this is done either by distilling in closed vessels, or by roasting the ore in a heap about 30 feet square, containing upwards of 2,000 tons, and yielding 20 tons of sulphur. This latter operation occupies five or six months.

Properties.—Sulphur gives off a peculiar smell when rubbed; has two distinct crystalline forms; one known as the octohedron with a rombic base, the other as the oblique prismatic form. The former kind of crystal occurs naturally, also when sulphur separates from a solution; the latter when sulphur is melted, partially cooled, and the fluid sulphur poured from the centre. Sulphur melts at 239°, becomes a yellow liquid between 250° and 280°; heated between 430° and 480° it has a dark treacly appearance, which is retained for some hours if poured into water; between 480° and 792° it becomes again limpid. Sulphur is insoluble in water, and without taste; is a bad conductor of heat; will crackle in the warm hand; an insulator of electricity; soluble in bisulphide of carbon; heated to 680°, and rapidly cooled, a black kind of sulphur is got *insoluble* in bisulphide of carbon; unites freely with chlorine, bromine, and iodine. Sulphur is in many respects like oxygen.

Tests.—Sulphur is converted into sulphuric acid, either by fusing with potash and nitre, or, if a fluid, by adding fuming nitric acid. It may then be precipitated by adding chloride of barium.

Uses.—In making matches; manufacture of gunpowder; as medicine; bleaching straw, &c., and in manufacture of sulphuric acid.

89. Sulphides, or Sulphurets.

Potassium, Protosulphide	K_2S
„ Bisulphide	K_2S_2
„ Tersulphide	K_2S_3
„ Tetrasulphide	K_2S_4
„ Pentasulphide	K_2S_5
Ammonium, Bisulphide	$(H_4N)_2S_2$
Calcium, Protosulphide	CaS
„ Pentasulphide	CaS_5
Cadmium, Sulphide, or Greenockite	CdS
Iron, Protosulphide	FeS
„ Bisulphide, or Iron Pyrites	FeS_2

Iron, Disulphide	$Fe_2 S$
„ Magnetic Sulphide	$Fe_7 S_8$
„ Arsenio Sulphide, or Mispickel	$Fe S As.$
Lead, Protosulphide, or Galena	$Pb S$
„ Subsulphide	$Pb_2 S$
Copper, Subsulphide	$Cu_2 S$
„ Sulphide	$Cu S$
„ Pyrites	$Cu Fe S_2$
„ Pentasulphide	$Cu S_5$
Gold, Bisulphide	$Au_4 S_4$
Sodium, Protosulphide	$Na_2 S$
„ Bisulphide	$Na_2 S_2$
„ Tersulphide	$Na_2 S_3$
„ Tetrasulphide	$Na_2 S_4$
„ Pentasulphide	$Na_2 S_5$
Barium, Sulphide	$Ba S$
Magnesium, Sulphide	$Mg S$
Zinc, Sulphide	$Zn S$
Cobalt, Protosulphide	$Co S$
„ Sesquisulphide	$Co_2 S_3$
„ Bisulphide	$Co S_2$
Nickel, Protosulphide, or Millerite	$Ni S$
Mercury, Sulphide, or Cinnabar	$Hg_2 S$
Manganese, Protosulphide	$Mn S$
Tin, Protosulphide	$Sn S$
„ Sesquisulphide	$Sn_2 S_3$
„ Bisulphide	$Sn S_2$
Silver, Sulphide	$Ag_2 S$
„ Ore (Red)	$3Ag_2 S, Sb_2 S$
Platinum, Protosulphide	$Pt S$
„ Bisulphide	$Pt S_2$
Bismuth, Sulphide	$Bi_2 S_3$

90. Compounds of Sulphur and Oxygen.

Sulphurous Anhydride	SO_2	= 64
Sulphuric Anhydride	SO_3	= 80
Sulphurous Acid	$H_2 SO_3$	= 82
Sulphuric Acid	$H_2 SO_4$	= 98
Hyposulphurous Acid	$H_2 S_2 H_2 O_4$	= 132
Hyposulphuric Acid, or Dithionic Acid	$H_2 S_2 O_6$	= 162
Trithionic Acid	$H_2 S_3 O_6$	= 194
Tetrathionic Acid	$H_2 S_4 O_6$	= 226
Pentathionic Acid	$H_2 S_5 O_6$	= 258

91. Sulphurous Anhydride, or Sulphurous Acid.

SO_2 = 64 ; Mol. Vol., □□ ; Sp. Gr., of Gas, 2·247 ; of Liquid, 1·38, at 60° F.

This gas may be obtained by burning sulphur in air or oxygen. It is, however, more commonly prepared by heating 2 or 3 ounces of sulphuric acid with half-an-ounce of copper turnings. The following equation represents the reaction :—

$$Cu + 2\,H_2SO_4 = Cu\,SO_4 + SO_2 + 2\,H_2O.$$

This gas has no colour; it is neither combustible nor a supporter of combustion; it is an important bleaching agent; it readily unites with water, forming sulphurous acid, H_2SO_3.

Sulphurous anhydride cannot be breathed when strong; has bleaching properties, the colours however restored by alkalies and stronger acids; very soluble in water, cold water dissolving about 40 times its bulk; solution tastes and smells similar to the gas itself, and if exposed to air, absorbs oxygen, converting the sulphurous into sulphuric acid; the solution undergoes no change when air is excluded; when sulphurous anhydride and watery vapour are passed into a vessel cooled below 17°, a hydrate is formed ($SO_2 + 15\,H_2O$). Sulphurous anhydride may be decomposed by potassium or sodium; decomposes chloric, bromic, and iodic acids, forming sulphuric acid, and setting free chlorine, &c.; may be condensed into a clear and colourless liquid which will dissolve bitumen; at—105° this liquid freezes into a transparent solid.

Other Preparations :—(2) By heating one part sulphur or charcoal with 12 parts sulphuric acid.

$$C + 2H_2SO_4 = 2SO_2 + CO_2 + 2H_2O.$$

(3). By heating four parts flowers of sulphur and five black oxide of manganese, or black oxide of copper.

$$S_2 + Mn\,O_2 = SO_2 + Mn\,S.$$

Uses.—Bleaches woollen, silk, and straw goods, by a process of deoxidation, forming colourless compounds; used to preserve meat; this gas is first produced in manufacture of sulphuric acid; used as an *antichlor* to remove excess of chlorine in bleached rags.

Tests.—Has smell of sulphur; is absorbed by peroxide of lead, forming white sulphate of lead.

92. Sulphites.

Sulphurous Acid is dibasic, forming two kinds of sulphites, viz.: an *acid* and a *neutral* sulphite; the sulphites are in many cases decomposed by a strong heat; when moist, they unite with oxygen of the air. Sulphuric and hydrochloric acids decompose them, giving off the sulphurous anhydride.

Normal Salt	$M_2 SO_3$
Acid Salt	$HM SO_3$
Double Salt	$MM SO_3$
Sulphite of Potassium	$K_2 SO_3$
Sulphite of Sodium	$Na_2 SO_3 . 7H_2 O.$
Sulphite of Calcium	$Ca SO_3$
Sulphite of Magnesium	$Mg SO_3$
Acid Sulphite of Potassium	$KH SO_3$
Acid Sulphite of Sodium	$NaH SO_3 4H_2 O.$
Sulphite of Barium	$Ba SO_3$
Sulphite of Lead	$Pb SO_3$
Sulphite of Silver	$Ag_2 SO_3$

93. Sulphuric Anhydride or Sulphuric Trioxide, SO_3; This is obtained by heating Nordhausen Acid in a glass retort, and condensing the fumes in a receiver surrounded by ice; may be also got by heating the acid Sulphate of Sodium ($NaH SO_4$); it is a white, fibrous, silky looking substance; has no acid properties; may be worked by the fingers without burning the skin; fumes in the air and readily absorbs moisture; hisses like hot iron when thrown into water; melts at 65° and boils at 110° forming a colourless vapour.

94. Sulphuric Acid, Oil of Vitriol, or Di-hydric Sulphate.

Sym., $H_2 SO_4$; Sp. Gr., Concen. 1.846.

Manufacture :—By burning Sulphur or iron pyrites in a furnace, sulphurous anhydride is produced; this is conducted into a large leaden chamber having a wooden framework: (the chambers vary in size, but generally from 12 to 15 feet high, 15 to 20 feet wide, and 150 to 300 feet long;) Nitric

Acid vapor is made to accompany the sulphurous anhydride by heating nitrate of sodium and oil of vitriol in an iron cup within the sulphur furnace; jets of steam are driven into the chamber; the bottom of the chamber is covered with water to the depth of two or three inches; an opening in the upper part of the extremity of the chamber allows the spent gases to escape. In this process nitric acid vapour is deoxidised, forming the peroxide of nitrogen; this gives off two atoms of its oxygen to the sulphurous acid, and thus converts it into sulphuric anhydride, and reduces the peroxide of nitrogen to nitric oxide; the nitric oxide is afterwards raised to the peroxide of nitrogen by its exposure to the air, and then gives off two atoms more of oxygen to the sulphurous anhydride vapour, and thus the reaction is repeated, the nitric oxide serving as a *carrier* of oxygen; thus with a very little nitre a large quantity of sulphuric acid can be prepared.

$$SO_2 + H_2O + N_2O_3 = H_2SO_4 + N_2O_2$$

The water at the bottom of the chambers absorbs the anhydrous acid, and is afterwards concentrated to 1.842 by heating in leaden, glass, or platinum stills.

Properties.—This is a heavy, colourless, and oil-like liquid; it blackens and destroys organic matter; freezes at —30° and boils at 640°; has strong affinity for water, producing great heat in combining with it; attracts moisture from the air; unites in all proportions with water, and the mixture occupies less space than the separate liquids; no smell; very acid taste; reddens vegetable blues; forms with oxides of the metals a great variety of sulphates; used for drying organic substances; dissolves most metals; it is *dibasic*; does not evaporate when exposed to air.

95. Second Hydrate of Sulphuric Acid.—(H_2SO_4, H_2O.) Has Sp. Gr. 1·78, and contains two atoms of water; freezes at 47°, having then Sp. Gr. 1·951; sometimes called Glacial Sulphuric Acid; boils at 435°.

96. Third Hydrate of Sulphuric Acid.—($H_2SO_4, 2H_2O$.) Got by evaporating weak sulphuric acid in vacuo at 212°; its Sp. Gr. is 1·632; boils at 348°.

97. Nordhausen Sulphuric Acid.—Got from sulphate of iron by first driving off by heat the water of crystallization, and then distilling in earthen retorts; prepared at Nordhausen, in Prussia, and Kraslitz, in Bohemia. In driving off the water of crystallization the weight is reduced about 40 per cent., and the sulphate becomes a reddish-yellow powder. About two pounds of this placed in a retort as a charge; about 36 hours occupied in distillation; there is thus obtained a brown oily fuming liquid with Sp. Gr. 1·9; used to dissolve indigo for dyeing Saxon Blue.

Test.—Chloride of barium gives immediate precipitate of sulphate of barium.

Uses.—Sulphuric acid has many and important uses. By it, nitric, hydrochloric, and other acids are obtained. It is used in manufacture of carbonate of sodium, &c. &c. 3000 tons of this acid are said to be used weekly in South Lancashire.

98. Sulphates.

Sulphates of potassium, barium, strontium, lead, and silver, and of both the mercury oxides, are anhydrous; sulphates of zinc, magnesium, and of the protoxides of iron, cobalt, and nickel, generally contain seven parts of water. The proportion of water is smaller in these sulphates if the crystals are formed at a high temperature, having only five, four, or two parts of water. Some of the alkaline sulphates are acid. Heated with charcoal all sulphates are decomposed. The sulphates of the alkalies and alkaline earths thus decomposed are converted into sulphides, which give off sulphuretted hydrogen when treated with hydrochloric acid.

Potassium, Sulphate		$K_2 SO_4$
Sodium,	„	$Na_2 SO_4 \; 10 H_2 O$
Potassium Acid, Sulphate		$KH SO_4$
Ammonium,	„	$(H_4N)_2 SO_4$
Calcium,	„	$Ca SO_4 . 2H_2 O$
Barium,	„	$Ba SO_4$
Strontium,	„	$Sr SO_4$
Lead,	„	$Pb SO_4$
Silver,	„	$Ag_2 SO_4$
Magnesium,	„	$Mg SO_4 . 7H_2 O$
Zinc,	„	$Zn SO_4 . 7H_2 O$
Iron,	„	$Fe SO_4 . 7H_2 O$
Cobalt,	„	$Co SO_4 . 7H_2 O$
Copper,	„	$Cu SO_4 . 5H_2 O$
Aluminum,	„	$Al_2 3SO_4 . 18 H_2 O$
Potash Alum		$K Al \; 2 SO_4 . \; 12 H_2 O$
Sulphate of Copper and Potassium,		$Cu SO_4 . K_2 SO_4 . 6H_2 O$
Basic Sulphate of Copper		$Cu SO_4 . 2 Cu H_2 O_2$

99. Sulphuretted Hydrogen, Hydrosulphuric Acid, or Dihydric Sulphide.

$H_2 S = 34$; Ccm. Vol., $\boxed{\;|\;}$; Sp. Gr., 1·1912.

This is a colourless gas, having a very offensive smell, like rotten eggs. It is also very poisonous. It is, however, very useful, for when it is brought in contact with many of the metallic salts in solution, it immediately forms *Sulphides* of the metals, having a distinctive colour, &c. The gas is readily prepared by adding water and sulphuric acid to the sulphide of iron.

$$Fe S + H_2 SO_4 = Fe SO_4 + H_2 S.$$

The lower animals are poisoned by it when mixed with from 600 to 1200 times its bulk of air; 100 cu. in. weigh over 38 grains ; reduced to a liquid by pressure of 17 atmospheres, forming a clear liquid which freezes at -122°. Water dissolves 2·66 times its own volume at 75°. The water solution is slightly acid, has a similar smell to the gas, and becomes milky if exposed to the air. The solution, as well as the gas, is used as an important test for many metallic oxides. Heated potassium burns rapidly in it ; chlorine, iodine, and bromine readily decompose it ; it burns with a pale blue flame; passed through a red hot tube it is decomposed; its composition shown by exploding 100 measures of the gas with 150 measures of pure oxygen, yielding 100 measures sulphurous anhydride.

Another Preparation.—By heating a mixture of powdered tersulphide of antimony and strong hydrochloric acid. This gives a purer gas.

$$Sb_2 S_3 + 6 H Cl = 2 Sb Cl_3 + 3 H_2 S.$$

Test.—A piece of blotting paper wetted with a solution of acetate of lead is immediately blackened on exposure to the gas, or its solution.

100. Bisulphide of Carbon or Sulphocarbonic Acid.

$CS_2 = 76$. Sp. Gr., 1.272 at 60° F.; Mol. Vol. ◫.

This is a liquid having a very disagreeable smell. It is highly inflammable, burning with a blue flame. It is very volatile, and its vapour is a powerful poison. It has never been frozen. It is prepared by dropping sulphur into a retort containing charcoal heated to redness; the sulphur vapour combines with the carbon and is condensed in cooled vessels.

Sulphurous and carbonic acid gases are produced when the liquid is burnt; has great refractive and dispersive power; it dissolves sulphur, phosphorous, chlorine, and bromine; may be regarded as the analogue of carbonic acid, the sulphur of the sulphide corresponding with the oxygen of the CO_2; unites with sulphides of alkaline metals producing *sulpho-carbonates*, as (K, CS_3) sulpho-carbonate of potassium; these sulpho-carbonates give a brown precipitate with salts of copper; the vapour of CS_2 mixed with oxygen is explosive; when heated with water in a sealed tube to 302° it is resolved into carbonic acid and sulphuretted hydrogen; has a burning taste; never been frozen, hence sometimes used in making thermometers; the vapour produces depression when breathed.

101. Selenium.

Se = 79.5. Atom. Vol. □; Sp. Gr. Cryst. 4.788.

This element as a powder is red. In many of its properties it resembles sulphur. After fusion it continues soft for some time, and may be easily moulded. It burns in air with a bright blue flame. It is found in small quantities in combination with lead, silver, copper, &c. In its preparation, the ore is heated in a crucible with nitrate and carbonate of potassium; it is then digested with water, adding hydrochloric acid; it is afterwards evaporated, and treated with sulphurous acid.

$$2H_2SeO_3 + 4H_2SO_3 = Se_2 + 4H_2SO_4 + 2H_2O.$$

It is a red powder; is semi fluid at 212°; boils at 1326°; its vapour is yellow; condenses in small drops having a metallic appearance; on becoming solid it is brittle and almost black; may be crystallised into four-sided prisms. Selenium does not dissolve in water; is soluble in strong sulphuric acid; burns with pale blue flame when heated in air, forming selenious anhydride.

102. Selenious Anhydride (SeO_2). This is prepared as above; has smell of horse-radish; not acid.

103. Selenious Acid. (H_2SeO_3). Obtained by dissolving selenium in warm nitric acid, and distilling the solution until the selenious acid is sublimed. It is a solid white substance; has acid taste; gives off yellow vapour; has strong affinity for bases, forming *Selenites*, which correspond with *Sulphites*.

104. Selenic Acid. (H_2SeO_4). Got by fusing selenium with nitrate of potassium; nitrate of lead is added, giving seleniate of lead, which is pp. by sulphuretted hydrogen; the acid in solution is separated by filtration. This acid closely resembles sulphuric acid; it dissolves gold; is decomposed when heated above 550°; great heat is evolved when mixed with water.

105. Seleniuretted Hydrogen. (H_2Se). This is a gas, and is prepared from a *selenide* in the same way as sulphuretted hydrogen. The gas has an offensive smell; is inflammable, and colourless.

106. Tellurium.

Te = 129; Sp. Gr. 6.65; Atom. Vol., □

This rare element is found chiefly in Hungary and Transylvania, united with gold, silver, and lead, forming tellurides of those metals. Tellurium has a metallic appearance like bismuth. In most respects it resembles sulphur and selenium. It combines with hydrogen, forming *telluretted hydrogen* (H_2Te) which is a gas having the smell of sulphuretted hydrogen. It forms with oxygen two acids—tellurous acid, $H_2\ TeO_3$, and telluric acid, $H_2\ TeO_4$.

107. Phosphorus.

P = 31. Atom. Vol. □ = ½; Sp. Gr., 1.83 (Solid), 4·5 (Vapour).

This remarkable element was discovered by Brandt in 1669. It is a solid wax-like substance, which, when pure, is soft and colourless. It takes fire very readily at a low temperature, or by friction, hence is usually kept in water. It is very poisonous. In the air it gives off a white vapour, which is phosphoric anhydride, $P_2\ O_5$. It is not found *free* in nature, but with oxygen and calcium it enters largely into the composition of the bones of animals. It is from this source that phosphorus is now obtained.

Preparation:—Gelatin is removed from the bones by heating them with water; the bones are afterwards distilled in closed vessels. Three parts of bone-ash thus obtained are mixed with two oil of vitriol, and about 20 water. After the mixture has stood two or three days, it is filtered.

$$Ca_3\ 2PO_4 + 2H_2\ SO_4 = H_4\ Ca\ 2PO_4 + 2Ca\ SO_4$$

The filtrate, which contains the *superphosphate of lime* ($H_4\ Ca\ PO_4$), is evaporated and mixed with one-fourth its weight of charcoal, and heated to dryness. It is finally distilled in an earthen retort, the phosphorus passing over as vapour into a vessel containing water.

First Stage of Decomposition—

$$3(H_4\,Ca\,2PO_4) = Ca_3\,2PO_4 + 4H_3\,PO_4.$$

Second Stage—

$$4H_3\,PO_4 + 16C = P_4 + 6H_2 + 16\,CO.$$

It melts at 111.5° and boils at 550°; when melted under an alkaline liquid it remains for a long time fluid, but if touched with a wire or glass rod it immediately becomes solid; is insoluble in water; its vapour is visible in the dark, hence its name which means "light bearing." If air is mixed with $\frac{1}{450}$th its volume of olefiant gas, a piece of phosphorus is not luminous in the dark; in pure oxygen it does not appear luminous under 60° unless the gas be rarified; it is soluble in benzol, oil of turpentine, and in the fixed and essential oils, and bisulphide of carbon; if a solution in the latter liquid be dropped on blotting paper, it takes fire as soon as the solvent has evaporated, in consequence of the rapid union of the phosphorus with oxygen of the air. Phosphorus may have five different forms. 1. *Transparent*, as above described. 2. *White*, which is less fusible. 3. *Black*, got by suddenly cooling melted phosphorus. 4. *Viscous*, by heating pure phosphorus to nearly boiling point and suddenly cooling. 5. *Red Scales*, by sublimation of phosphorus.

Tests:—Its garlic smell; its luminosity in the dark; in doubtful cases, dissolve substance in bisulphide of carbon, filter, place filtrate into a watch glass on hot water in the dark, a luminosity appears as sulphide evaporates.

108. Red or Amorphous Phosphorus, Sp. Gr., 2.14.—This is red and opaque; insoluble in bisulphide of carbon or benzol, and so may be distinguished from the common kind; chlorine acts on it without heat; detonates when rubbed with chlorate of potash; is not poisonous; not luminous in the dark until heated to 393°; does not oxidise in the air; heated to 500° it melts and burns with bright flame.

Preparation.—It is obtained by heating in a flask, common phosphorus at about 450°, for 30 or 40 hours, excluding air.

109. Lucifer Matches.

In their manufacture the ends of the pieces of wood are dipped in gum and then dusted over with sulphur; after this they are tipped with a mixture of glue, phosphorus, and chlorate or nitrate of potassium and oxide of manganese. Red phosphorus is said to be preferable to the vitreous, being attended with less danger in their manufacture, and less injurious to the health of the workpeople. The last-named matches are not, however, in use now, not being sufficiently inflammable, and giving a sputtering flame. Many matches now made without phosphorus, having, instead, sulphide of antimony, silica, and nitrate of lead. The following compositions are in use—

Phosphorus (common)	4	Phosphorus (common)	9
Saltpetre	16	Saltpetre	14
Red Lead	3	Black Oxide of Manganese	14
Strong Glue	6	Gum	16

110. Oxides of Phosphorus.

There are two known *oxides* of Phosphorus, Phosphorus Anhydride or Phosphoric Trioxide, $P_2 O_3$. Phosphoric Anhydride or Phosphoric Pentoxide, $P_2 O_5$.

There are also three *oxidised acids*, or oxides of phosphine, PH_3.

Hypophosphorous Acid (monobasic)...$PH_3O_2 = HPH_2O_2$
Phosphorous Acid (dibasic) ....$PH_3O_3 = H_2PHO_3$
Phosphoric Acid (tribasic) ....$PH_3O_4 = H_3PO_4$

There are three *hydrates* of phosphoric acid.

Ordinary Phosphoric or Orthophosphoric Acid.....$H_3 PO_4$
Metaphosphoric Acid....................................$H PO_3$
Pyrophosphoric Acid ....$H_4 P_2O_7$

111. Phosphorous Anhydride, $P_2 O_3$ This is obtained by the *slow* combustion of phosphorus in dry air or oxygen. This forms large white flakes, which are volatile and do not redden litmus paper. When brought in contact with water produces a hissing sound, and forms *Phosphorous Acid.*

112. Phosphorous Acid or Hydric Phosphite, $H_3 PHO_3$. This acid is formed, also when sticks of phosphorus are exposed to moist air, or by the action of water on the trichloride of phosphorus.

$$3H_2O + PCl_3 = PH_3O_3 + 3HCl.$$

When the solution is boiled, the hydrochloric acid is driven off, and on cooling, crystals of phosphorous acid are formed. The solution is a strong acid, and a powerful reducing agent. It is *dibasic*.

113. Phosphites.—Phosphorous acid being *dibasic* forms two classes of salts, *normal* and *acid* (*par.* 27, *Salts*). Exs. *Normal* phosphite of sodium, $Na_2 PHO_3, 5H_2O$; *acid* phosphite of barium, $BaH_2 2PHO_3$. *Neutral* or *normal* phosphites, excepting those of the alkaline metals are but slightly soluble, whilst *acid* phosphites are soluble. Acid phosphites heated give off hydrogen.

$$BaH_2 2PHO_3 = Ba 2PO_3 + 2H_2$$

Neutral phosphites heated yield phosphuretted hydrogen.

$$5Pb PHO_3 = Pb_3 2PO_4 + Pb_2 P_2 O_7 + H_3 P + H_2$$

Phosphites are distinguished by their solution reducing sulphurous acid, giving off sulphuretted hydrogen—

$$3H_2 PHO_3 + H_2 SO_3 = 3H_3 PO_4 + H_2 S.$$

114. Hypophosphorous Acid, $HPH_2 O_2$. This compound has never been obtained anhydrous; the syrupy solution has a sour and somewhat bitter taste; slightly acid; absorbs oxygen from air; on heating, it first loses water, and with greater heat it is resolved into phosphoric acid and phosphuretted hydrogen.

Preparation.—Produced by boiling phosphorus in solution of caustic potash or lime; may be got as hydrate by boiling phosphorus in water with baryta.

$$3(BaO, H_2O) + 2P_4 + 6H_2O = 3(Ba2PH_2O_2) + 2H_3P.$$

By adding sulphuric acid to solution of hyphophosphite of barium, the barium is removed as sulphate, and hypophosphorous acid remains in solution.

115. Phosphoric Anhydride, Phosphoric Pentoxide, or Pentoxide of Phosphorus, $P_2O_5 = 142$. This is a white, anhydrous, and very deliquescent powder; readily combines with water, producing a hissing sound when thrown into it; water of the hydrate can only be removed by causing the acid to unite with a base; has a pleasantly sour

taste; is not poisonous; reddens litmus paper; is a useful dehydrating agent, having so strong an affinity for water; will remove water from hydrate sulphuric acid when heated with it.

$$P_2O_5 + 3H_2SO_4 = 2(H_3PO_4) + 3SO_3$$

Used medicinally; dissolves phosphate of lime, hence destructive to the teeth; is decomposed when heated with charcoal, being resolved into carbonic anhydride, carbonic oxide, and phosphorus.

$$P_2O_5 + 4C = CO_2 + 3CO + 2P.$$

***Preparation.*—This is got most simply by burning phosphorus under a bell jar, in dry air or oxygen.**

116. Orthophosphoric Acid, Common Phosphoric Acid, or Tribasic Phosphoric Acid.

$$H_3PO_4$$

Preparation.—1. This form of the acid may be obtained by boiling 1 part of Phosphorus with 13 of nitric acid; nitric acid is decomposed, yielding deutoxide of nitrogen (NO) which escapes while Phosphoric Acid remains in solution; on the disappearance of the phosphorus, the excess of nitric acid is evaporated until white fumes come off; the acid solidifies as it cools; this is Glacial Phosphoric Acid.

2. May be also obtained by adding carbonate of ammonium to superphosphate of lime (*See Manufacture of Phos.*); Tribasic Phosphate of Lime is precipitated and phosphate of ammonium is in solution; the latter is separated by filtration, and then ignited; this method yields a less pure acid than the first.

Properties.—May be obtained as *Glacial* acid, when it is in hard prismatic crystals; the aqueous solution has a strong acid reaction, and at a boiling heat decomposes the salts of most volatile acids.

117. Orthophosphates or Tribasic Phosphates.

Phosphates may be formed in which one, two, or three atoms of water are displaced by as many atoms of some metallic base; by adding carbonate of sodium to a boiling solution of glacial acid, a tribasic phosphate of sodium is got.

$$(Na_2 HPO_4, 12H_2 O)$$

By mixing a solution of this with a solution of acetate of lead, a white phosphate of lead may be obtained. On passing sulphuretted hydrogen through the liquid with the last salt suspended, phosphoric acid is set free, and is found in solution, whilst the sulphide of lead is formed.

$$Pb_3 2PO_4 + 3H_2 S = 2H_3 PO_4 + 3PbS.$$

By filtration the acid may be separated and crystallized; generally speaking the phosphates, with 3 atoms of metallic base, are alkaline, with two atoms either neutral or but feebly alkaline, and with one strongly acid; the last sometimes called *superphosphates*.

Test.—With nitrate of silver, a yellow precipitate.

118. Pyrophosphoric Acid ($H_4 P_2 O_7$) and **Pyrophosphates** ($M_4 P_2 O_7$).—The pyrophosphate of sodium is produced by heating disodic orthophosphate to redness.

$$2 Na_2 H PO_4 = Na_4 P_2 O_7 + H^2O.$$

When the nitrate of lead or silver is added to a solution of the pyrophosphate of sodium, it yields insoluble pyrophosphates of those metals :—

$$Na_4 P_2 O_7 + 2 Pb'' N_2 O_6 = Pb'' P_2 O_7 + 4 Na NO_3.$$

When sulphuretted hydrogen is passed into the solution, it yields pyrophosphoric acid :—

$$Pb''_2 P_2 O_7 + 2 H_2 S = H_4 P_2 O_7 + 2 Pb'' S.$$

The acid thus produced does not, in solution, precipitate *albumen* ; when *neutral*, gives a white pp. with chloride of barium, and nitrate of silver.

119. Metaphosphoric Acid ($H PO_3$) **and Metaphosphates** ($M PO_3$).—Metaphosphoric acid is obtained by heating pyrophosphoric acid to dull redness. It gives a white pp. with *albumen*, nitrate of silver, and chloride of barium. As a solid, it is colourless and glassy.

The metaphosphates may be obtained by treating the acid with bases.

120. I. Orthophosphates.

$M_3 PO_4$; $M_2 H PO_4$; $M H_2 PO_4$.

Sodium, Subphosphate	$Na_3 PO_4 . 12 H_2 O$.
„ Rhombic phosphate	$Na_2 H PO_4 . 12 H_2 O$.
„ Acid phosphate	$Na H_2 PO_4 . H_2 O$.
Microcosmic Salt	$Na H_4 NHPO_4 . 4 H_2 O$.
Calcium, Basic phosphate	$Ca''_3 2 PO_4$.
„ Superphosphate	$Ca'' H_4 2 PO_4$.
Magnesium and Ammonium, Phosphate	$Mg'' H_4 N, PO_4 . 6 H_2 O$.
Ferricphosphate	$Fe''' PO_4 . 2 H_2 O$.
Lead, Phosphate	$Pb''_3 2 PO_4$.
Bismuth, „	$Bi''' PO_4$.
Silver, „ (yellow).	$Ag_3 PO_4$.

II. Metaphosphates $M PO_3$.

Sodium, Metaphosphate	$Na PO_3$.
Lead, „	$Pb'' 2 PO_3$.
Silver, „	$Ag PO_3$.

III. Pyrophosphates $M_4 P_2 O_7$; $M M'_3 P_2 O_7$.

Sodium, Pyrophosphate	$Na_4 P_2 O_7 . 10 H_2 O$.
Lead, „	$Pb''_2 P_2 O_7$.
Copper and Sodium, Pyrophosphate	$Cu''_3 Na_2 2' P_2 O_7$.
Silver, „	$Ag_4 P_2 O_7$

121. Oxide of Phosphorus, $P_4 O$.—This is a constituent of the yellow substance that remains when phosphorus is burnt in air. It is neither acid nor alkaline, and has neither taste nor smell.

122. Phosphides of Hydrogen.

There are three Phosphides of Hydrogen:—

Gaseous Phosphuretted Hydrogen, H_3P.
Liquid Phosphide of Hydrogen, H_2P.
Solid Phosphide of Hydrogen, HP_2.

123. Phosphuretted Hydrogen.

$H_3P = 34.$

This is a remarkably-inflammable gas, having a peculiar smell, like garlic. It bursts into flame when it comes in contact with air or oxygen. It is easily prepared by boiling small pieces of phosphorus in a solution of caustic potash or lime. Besides the gas, the hypophosphite of potassium is formed :—

$$P_4 + 3\,H_2O + 3\,KHO = 3\,KPH_2O_2 + H_3P.$$

A drop or two of sulphuric ether added, prevents too violent an explosion of the gas in the flask.

This gas is somewhat soluble in water ; is decomposed when passed through solutions of lead, copper, or mercury, producing phosphides of those metals. Solution of chloride of lime completely absorbs it when pure ; mixed with air or oxygen, it explodes at 300° temperature. One volume of phosphorous vapour and six vols. of hydrogen are condensed in this gas into four vols. Similar to ammonia in its composition, but has not alkaline properties ; combines with some acids, as hydriodic acid, H_3P, HI. This is a crystalline compound, similar to sal ammoniac ; H_3P bursts into flame on coming in contact with air or oxygen. This property is destroyed by adding to the gas small quantities of ether, naphtha, &c.

124. Liquid Phosphide of Hydrogen, H_2P.—This liquid occasions the spontaneous inflammability of *phosphuretted hydrogen* in air; it is said to communicate this property to 500 times its weight of the gas; it is a colourless liquid, which is insoluble in water.

It is prepared by the action of water on phosphide of calcium.

$$5\,PCa^2 + 5\,H_2O = 5\,Ca_2O + 5\,PH_2.$$

The gas obtained is condensed in a cooled U-tube.

125. Solid Phosphide of Hydrogen, HP_2.—When the above liquid is exposed to sunshine, the *solid* form of the compound is found on the sides of the glass. It may be got, too, by the action of hydrochloric acid on the liquid. The solid is a yellowish compound, which takes fire at 150°.

126. Terchloride of Phosphorus, $PCl_3 = 137.5$. Sp. Gr. of Liquid is 1.616 ; Mol. Vol. —This is a colourless and transparent liquid ; has a pungent smell ; fumes when exposed to air ; boils at 173° 4; mixed with water it is decomposed into hydrochloric and phosphorous acids ; it dissolves phosphorus ; is decomposed by alcohol and ether ; is prepared by passing dry chlorine into melted phosphorus.

127. Pentachloride or Perchloride of Phosphorus, $PCl_5 = 208.5$; Mol. Vol.

This is a snow-white crystalline solid, which volatilises below 212° ; may be fused under pressure ; fumes when exposed to air ; very deliquescent ; is decomposed by water into phosphoric and hydrochloric acids ; burns in the flame of a lamp, yielding chlorine and phosphoric acid ; got by treating terchloride of phosphorus, in a tall glass, with excess of chlorine.

128. Silicon, or Silicium.

Si = 28 ; Sp. Gr. of Vapour, 0.9674.

Lately shown by Deville to be similar to Carbon in having three modifications, *Amorphous*, *Graphitoid*, and *Crystalline* ; next to oxygen found most abundantly in nature ; principal element in flint, quartz, and sandstone ; found naturally as silica ; pure silicon first obtained by Berzelius, in 1823.

Amorphous Silicon.—Properties.—This is, when pure, a dark brown powder, heavier than water ; soils the fingers ; is a non-conductor of electricity ; is non-volatile ; without lustre ; does not melt before the blowpipe ; does not dissolve in water ; neither nitric nor sulphuric acid acts on it ; dissolves in hydrofluoric acid and warm solution of potash ; when strongly ignited, increases in weight, and has a chocolate colour ; heated in air or oxygen it burns brightly, and is converted into silica ; heated with sulphur it unites with that element ; the chocolate variety will not combine with sulphur when heated with it, will not dissolve in hydrofluoric acid, nor burn in the air. Silicon, when melted with dry carbonate of sodium, is converted into silicic acid.

Amorphous Silicon corresponds with the *lampblack* form of carbon.

Preparation.—Got by mixing powdered fluor-spar and flints with oil of vitriol, then heating the mixture. The fluoride of silicon as a gas comes off and is conducted into water, rendering it acid ; on adding a solution of potash, the acid liquid is neutralized, and the double fluoride of silicon and potassium is formed ; this is dried and heated with about nine-tenths its weight of potassium, giving this reaction :—

$$(2\,K\,F,\ Si\,F_4) + 2\,K_2 = Si + 6\,K\,F.$$

The silicon is washed in cold water to remove potassium ; when it ceases to give an alkaline reaction, it is boiled with water, to decompose any remaining fluoride. It may also be obtained by passing the vapour of chloride or fluoride of silicon over potassium, and then washing with cold water.

Graphitoid Silicon.—Got by fusing in a crucible 5 parts soluble glass, (silicate of potassium) 10 parts cryolite (fluoride of sodium and aluminum), with 1 part aluminum. The silicon is separated as scaly crystals, on adding hydrochloric acid. This has a Sp. Gr. of 2.49 ; has metallic lustre ; is similar to graphite when separated from iron ; conductor of electricity ; undergoes no change when heated to white heat in oxygen ; may be gradually dissolved by a mixture of hydrofluoric acid and nitric acid.

Crystalline Silicon.—Prepared by Deville, by mixing in red-hot earthen crucible, 3 parts silico-fluoride of potassium, 1 part sodium, and 1 part zinc. These are fused, and afterwards cooled. Needles of silicon are found in buttons of zinc ; zinc separated by digesting in hydrochloric acid, and afterwards in boiling nitric acid.

129. Silicic Anhydride or Silica.

$Si\,O_2 = 60$; Sp. Gr. 2.642 (Cryst.)

Found in nature pure as rock-crystal, and some kinds of quartz; nearly pure in sand, flint, opal, agate, calcedony, and jasper.

Properties.—When pure perfectly transparent and colourless; very hard; fuses by heat of oxyhydrogen blow-pipe into a transparent glass; insoluble in water and all acids except hydrofluoric; as found in rock-crystal crystallized in six-sided prisms and terminated by six-sided pyramids; not volatile when heated alone; all waters contain this acid; hot springs, as the Geysers, deposit it.

Preparation.—1. May be obtained by passing fluoride of silicon into water, and afterwards washing and igniting.

$$3SiF_4 + 2H_2O = SiO_2 + 2(2HF, SiF_4)$$

2. By heating colourless rock-crystal to redness, and then, whilst hot, immersing in water.

Tests.—Evaporate solution to dryness, when it appears as gritty white powder, insoluble in water or weak acids; the solid fused with carbonate of sodium before the blow-pipe gives a transparent colourless bead.

130. Silicates.

Most of the silicates are found as crystallized minerals; many of them are double silicates; most are fusible. Nearly all are insoluble in water; definite hydrates difficult to obtain; $2SiO_2, 3H_2O$ has been got as well as some others.

Forge Cinder........................$Fe''_2 SiO_4$
Silicate of Lime ....$Ca''_2 SiO_4 2SiO_2$
Wollastonite ....$Ca'' SiO_3$
Augite ....$(Ca Mg)'' SiO_3$

131. Fluoride of Silicon, SiF_4 **Sp. Gr.,** 3.6; **Mol. Vol.** ◫. This is a gas which fumes in the air; it has been liquified; and the liquid may be solidified at -220°. It is prepared by heating in a flask equal parts of *fluorspar* and glass in fine powder, with 12 times their weight of oil of vitriol.

$$CaF_2 + H_2SO_4 = 2HF + CaSO_4$$

$$\text{Then—}4HF + SiO_2 = 2H_2O + SiF_4$$

132. Hydrofluosilicic Acid or Silicofluoric Acid, $2HF, SiF_4$. When the above gas is passed through water, one portion of the gas is *decomposed*, and another is *dissolved*, forming the hydrate of silica, a white gelatinous substance, and a solution of the hydrofluosilicic acid.

$$3SiF_4 + 2H_2O = SiO_2 + 2(2HF, SiF_4).$$

This liquid precipitates potassium and barium.

133. Glass,

Glass is a combination of two or more Silicates, one being a silicate of an *alkali*, whilst the other is either a silicate of lime, barium, oxide of lead or iron. Glass is obtained by melting silicic acid with metallic oxides; when cool it is transparent or coloured, according to the oxides used.

134. **Plate and Window Glass.**—This consists of silicates of sodium and lime; at St. Gobain the following ingredients are used:—300 parts white sand, 100 dry carbonate of sodium, 43 lime, slaked in air; 300 broken glass; these are melted in a large crucible, and remain in a state of fusion for some hours; the liquid is then ladled into a smaller crucible, and thence poured upon a cast iron table; the melted mass is then rolled, and afterwards annealed and levelled.

135. **Window Glass** is manufactured from a mixture of 100 parts of sand, 35 to 40 chalk, 30 to 35 soda ash, and from 50 to 150 broken glass.

136. **Bohemian Glass.**—This is composed chiefly of silicates of potassium and lime, and may be represented by ($K_2O, 3SiO_2, CaO, 3SiO_2$); used for combustion tubing, and known as *hard-glass tubing.*

137. **Bottle Glass.**—This contains silicates of aluminum, lime, iron, magnesium or potassium. May be prepared from 100 parts sand, 80 soapers' waste, 80 gas lime, 5 clay, 3 rock salt; used for bottles, carboys, &c; green colour occasioned by ferrous oxide.

138. **Flint Glass.**—This may be represented by ($K_2O, 3SiO_2, PbO, 3SiO_2$) consisting of the silicates of potassium and lead; usual charge, 100 parts fine sand, 100 minium or *red lead,* 30 refined pearl ash; used for optical instruments, &c.

139. **Devitrification.**—When glass is kept for a long time at a temperature near the melting point, it becomes opaque, and is said to be *devitrified*; it is known also as *Réaumur's Porcelain.*

140. **Soluble Glass** ($Na_2O, 4SiO_2$), is an alkaline silicate, got by melting together 8 parts carbonate of sodium, 15 pure quartz sand, and 1 part charcoal. It is used in fixing fresco colours; for protecting stonework, and in preparing mordanted calico.

141. **Coloured Glass.**—Sesquioxide of iron, suboxide of copper, and gold, give a *red* colour; antimony gives a *yellow* colour; protoxide of iron and oxide of copper give a *green*, and cobalt a *blue.*

142. Boron:

B = 10.9; Sp. Gr. 2.68.

This element was obtained from Boracic Acid by Gay-Lussac, Thenard, and Davy, in 1808. It may be obtained like Silicon in three forms, the *Crystalline*, *Graphitoid*, and *Amorphous*.

Amorphous Boron.—Got by the same method as amorphous silicon; hydrofluoric acid is saturated with boracic acid; to the liquid is then added carbonate of potassium; the compound is afterwards washed and dried; is finally heated with equal weight of potassium in iron crucible; fluoride of potassium is removed by hot water.

$$2(KF, BF_3) + 3K_2 = 8KF + 2B.$$

This form of Boron is a dark greenish-brown, or chocolate-coloured powder; without taste or smell, and similar in appearance to carbon; may be liquified by voltaic electricity; does not oxidise in air, water, or solutions of the alkalies; is readily oxidised by nitric acid, or aqua regia; it is rapidly oxidised by heating with nitrate of potassium, deflagrating powerfully; when first prepared it has a strong affinity for oxygen, as may be shewn by heating in air or oxygen, when it burns with bright scintillations; it unites readily with chlorine.

Crystalline Boron.—This is obtained from the amorphous variety by heating it with aluminum in a Hessian crucible for about two hours; the aluminum is afterwards dissolved out by dilute hydrochloric acid. This form of boron is in transparent but dark brown octohedra crystals rivalling the diamond in brilliancy, burns imperfectly in oxygen, but readily when heated in chlorine; is not affected by any acid or mixture of acids.

Graphitoid Boron is obtained in preparing the crystalline form, and is separated similarly. Appears as pale copper-coloured, opaque, hexagonal scales.

143. Boracic Anhydride.

$B_2O_3 = 69.8$; Crystallized Acid HBO_2, H_2O; Sp. Gr. 1.83.

This is found in *tincal* obtained from Thibet, and in borate of lime and magnesium from west coast of S. America; met with in greatest abundance in Tuscany, where it rises with jets of steam called *Suffioni*; the vapour falls into lakes of water surrounding the jets; this water, on evaporation in leaden vessels, yields the crude boracic acid; the heat required for evaporation is supplied by conveying the *Suffioni* in pipes below the vessels; crude acid only yields about three-quarters of its weight of pure acid.

Properties.—Gentle heat causes the crystals to part with water, and become a hard, transparent, and colourless glass; this after a time becomes opaque; bodies with which it is combined are rendered easily fusible; it is soluble in alcohol; the alcoholic solution burns with green flame; is sparingly soluble in cold water, but is dissolved by three times its weight of boiling water; slightly more powerful than carbonic acid, which it will displace.

Pure Boracic Acid is obtained by dissolving 1 part of purified borax in 2½ parts of water, and then adding hydrochloric acid; here chloride of sodium remains in solution, whilst the boracic acid crystallizes out.

144. **Borates.**—The alkaline borates are very soluble; other borates only partially; a great variety of alkaline borates.

Test.—Turmeric paper soaked in alcoholic solution of the acid becomes quite red on drying.

Additional Non-Metallic Compounds.

145. **Chloroperchloric Acid,** $Cl_6\,O_{17}$?—Prepared by exposing chlorous anhydride to the rays of the sun. It is a reddish brown liquid; decomposed by heat; forms white fumes when in contact with moist air.

146. **Chlorochloric Acid,** $Cl_6\,O_{13}$?—Obtained by passing *euchlorine* through a number of U-tubes, surrounded by a freezing mixture. It is a yellowish red liquid which boils at 89°.6 F.

147. **Chloride of Bromine,** Br Cl.—Got by passing chlorine through bromine. It is a yellow liquid, having a penetrating odour; very volatile, and bleaches vegetable colours.

148. **Bromide of Nitrogen,** N Br ?—This is prepared by the action of bromide of potassium on chloride of nitrogen. It is an oily, volatile, dark brown, and explosive liquid.

149. **Protochloride of Iodine,** I Cl.—Got by the distillation of 1 part iodine, and 4 parts chlorate of potassium. It is a reddish-brown and oily-looking liquid.

150. **Terchloride of Iodine,** $I\,Cl_3$ —Produced by the action of chlorine on iodine. It is a yellow solid substance.

151. **Bromide of Iodine,** I Br.—This is obtained by treating iodine with bromine. It is a volatile solid.

152. **Chlorosulphuric Acid, or Chloride of Sulphuryl, SO_2Cl_2.** This is produced by exposing equal volumes of chlorine and sulphurous anhydride to the action of the sun. It is a colourless liquid, having a penetrating odour.

153. **Nitrosulphuric Acid,** $H_2SO_8 2NO$.—This acid has never been isolated.

154. **Persulphide of Hydrogen,** H_2S_3?—This is procured by the addition of hydrochloric acid to the persulphide of calcium (CaS_5), and gently warming. It is a yellow, oily liquid, with smell of sulphuretted hydrogen.

155. **Chloride of Sulphur,** S_2Cl_2 :—Got by passing dry chlorine through melted sulphur. It is a yellow, volatile liquid, which fumes in the air.

156. **Sulphide of Nitrogen,** SN:—Obtained by passing gaseous ammonia, through a solution of chloride of sulphur, in bisulphide of carbon. It forms golden yellow crystals.

157. **Chloride of Boron,** BCl_3 :—This is a gas which fumes in the air, and is decomposed by water. It is prepared by passing dried hydrochloric acid over crystals of boron.

158. **Fluoride of Boron,** BF_3 :—Got by igniting 2 parts *fluorspar* with one part boracic anhydride. It is a gas having an irritating smell.

159. **Nitride of Boron,** BN:—This is a white powder, which is procured by heating to redness 1 part anhydrous borax, with two parts sal ammoniac.

160. **Phosphorus, Oxychloride of,** $POCl_3$:—Obtained by decomposition of pentachloride of phosphorus in moist air. This is a colourless and fuming liquid.

161. **Sulphochloride of Phosphorus,** $PSCl_3$:—Got by the action of pentachloride of phosphorus on trisulphide of antimony. It is a colourless and oily liquid.

162. **Terbromide of Phosphorus,** $POBr_3$:—Prepared like oxychloride of phosphorus.

163. **Biniodide of Phosphorus,** PI_2 :—Prepared by adding iodine to a solution of phosphorus in bisulphide of carbon. It forms crystals of a bright orange colour.

164. **Teriodide of Phosphorus,** PI_3 :—Obtained by similar method as *biniodide*. Crystals are dark red, and deliquesce in air.

165. **Phospham,** HN_2P:—Got by passing gaseous ammonia over pentachloride of phosphorus, and heating the product in a current of carbonic anhydride. It is a reddish powder.

166. **Hydride of Silicon,** $H_4 Si$? :—Prepared by decomposing silicide of magnesium, by hydrochloric acid.

167. **Sulphide of Silicon,** $Si S_2$:—Obtained by passing bisulphide of carbon vapour over a mixture of silica and carbon.

168. **Chloride of Silicon,** $Si Cl_4$:—Got by heating silicon in chlorine. This is a volatile, transparent, and colourless liquid, having an acid, pungent odour.

169. **Bromide of Silicon,** $Si Br_4$:—Prepared in the same manner as the chloride.

170. **Hydrochlorate of Silicon,** $Si_3 H_4 Cl_{10}$:—Obtained by passing dry hydrochloric acid over heated crystallized silicon. This is a fuming and colourless liquid. It is inflammable, and burns with a greenish flame.

PART II.

METALS.

171. Classification of Metals.

ALKALIES.

Potassium, Sodium and Lithium. ***Rubidium*** **and** ***Cæsium.***

ALKALINE EARTHS.

Barium, Strontium and Calcium.

EARTHS.

Aluminum, ***Glucinum, Zirconium, Thorinum, Yttrium, Erbium, Terbium, Cerium, Lanthanum,*** **and** ***Didymium.***

MAGNESIAN METALS.

Magnesium, Zinc, and Cadmium.

ANALAGOUS TO IRON.

Iron, Manganese, Cobalt, Nickel, ***Uranium,*** **Chromium.**

ACID FORMERS.

Tin, Arsenic, Antimony, Bismuth, ***Tungsten, Titanium Columbium, Tantalum, Molybdenum, Vanadium.***

METALS.

Copper, Lead, *Thallium.*

NOBLE METALS.

Gold, Silver, Mercury, Platinum, *Palladium, Rhodium, Ruthenium, Osmium, Iridium.*

MILLER'S ELEMENTS OF CHEMISTRY.

Potassium and its Compounds.

K = 39.1; Sp. Gr., 0.865; Fusing-pt., 144°.5.

172. **Potassium** is found in the following natural substances, *felspar, mica, nitre,* sea-water, and salt deposits, &c. The metal is obtained by decomposing carbonate of potassium with charcoal, at a great heat. Crude tartar (acid tartrate of potassium) is well dried in a crucible; it is afterwards withdrawn, broken into small pieces, and put into a wrought iron retort; it is then heated to a reddish white heat, when the potassium is evaporated, and condensed in a vessel containing naphtha; it is furnished pure by redistillation.

$$K_2 CO_3 + C_2 = K_2 + 3CO.$$

This is a silver-white metal; can be cut with a knife; it readily oxidises in air or water, and hence is kept in benzol or naphtha; when thrown on water it immediately takes fire and burns with a violet flame; the reaction is thus shown—

$$2H_2 O + K_2 = 2KHO + H_2$$

Discovered by Davy in 1807; unites with chlorine, sulphur, and other metalloids.

173. Oxides of Potassium.—There are three oxides of this metal :—

1. Potash, or Potassium Monoxide ....K_2O
2. Deutoxide of Potassium, or Potas. dioxide ...K_2O_2*
3. Peroxide, or Potassium tetroxide ....K_2O_4†

174. Potash—$K_2O = 94.2$.—This may be got by heating potassium with equivalent quantity of the *hydrate*, when the following reaction takes place :—

$$2KHO + K_2 = 2KKO + H_2$$

It may be obtained too by exposing potassium to dry air or oxygen. This is a white caustic substance which fuses when heated to redness; when water has been added to it, heat will not expel it.

175. Hydrate of Potash or Caustic Potash, $KHO = 56.1$.—This is prepared by boiling 1 part carbonate of potassium in 12 parts of water, and adding about half as much caustic lime as carbonate of potassium :

$$K_2CO_3 + CaH_2O_2 = 2KHO + CaCO_3$$

On evaporating the liquid, the caustic is obtained, which, when fused, is a white and hard substance; it dissolves in half its weight of water; it has a burning taste; is a powerful cautery, destroying in a short time animal and vegetable bodies; the solution is best clarified by decanting; it is a most useful reagent, and is employed extensively in the arts of soap-boiling, glass-making, &c.

176. Liquor Potassæ contains about 6 per cent. solid hydrate, and has a sp. gr. of 1.058.

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* Formed by oxidation of potassium in dry air.

† Obtained by heating potassium in a current of dry air, and afterwards in that of oxygen.

177. Carbonate of Potassium, K_2CO_3 = Sp.Gr., 2.207. This salt is obtained from the ashes of plants; plants are burnt in pits; the ashes are lixiviated; on evaporating the solution to dryness, the *potashes* of commerce are obtained; these calcined yield *pearlash;* by heating to redness in a crucible, cream of tartar and nitre, a more pure carbonate may be obtained. The salt is alkaline and deliquescent; 100 parts of water at 60° dissolve 90 of the salt; it fuses at a red heat, and at a very high temperature volatilizes. Is largely used in manufacture of soap and glass.

178. Bicarbonate, or Acid Carbonate of Potassium, or Hydric Potassium Carbonate, $KHCO_3$. Sp. Gr., 2.05. This is prepared by passing carbonic acid through a strong solution of carbonate of potassium; the bicarbonate crystallizes, forming right rhombic prisms. It is a white salt, used extensively with citric or tartaric acid for effervescing drinks; has no alkaline reaction on turmeric paper.

179. Nitre, Saltpetre, or Nitrate of Potassium, KNO_3. Sp. Gr. 2.07. This salt is met with *naturally* on, or near the surface of the soil, in many parts of the East Indies; by lixiviating the soil, and allowing the solution to stand, the salt is obtained in crystals. In France, Prussia, Sweden, &c., nitre has for some time been prepared *artificially* by a process of *nitrification.* Heaps are formed of wood ashes, animal matter, and lime; the heaps are covered so as to admit the air, but exclude rain; they are at intervals watered with liquid manure and turned over; on washing the earth, nitre is got in crystals from the solution; the process of *nitrification,* it is thought, arises from the slow combination of atmospheric oxygen and nitrogen; in the *nitre plantations* of Prussia, one cubic foot of earth furnishes 20 ounces of nitre.

Properties.—Saltpetre dissolves in about 7 times its weight of water at 32°; it is a powerful oxidising agent; when fused and cast in moulds, it is known in commerce as *sal prunelle*; the taste is cooling; *fulminating powder* is formed by a mixture of 3 parts nitre, 2 carbonate of potassium, and 1 sulphur; nitre is decomposed at a red heat, giving off oxygen.

180. Gunpowder consists of a mixture of nitre, charcoal, and sulphur, in different proportions, according to the purpose for which it is prepared. Common gunpowder contains the following per centages—saltpetre 75, charcoal 12.5, and sulphur 12.5. These substances are mixed, made into a paste with water, and ground; it is afterwards pressed, forming *press cake*, then broken into small pieces; sifted, and finally *glazed* by revolving in a barrel. The explosiveness of gunpowder depends upon the sudden formation of nitrogen, carbonic anhydride, and carbonic oxide, occupying 1500 times the space of the gunpowder used. The following equation is thought to represent the reaction when gunpowder is fired—

$$S_2 + 6C + 4KNO_3 = 6CO_2 + 2N_2 + 2K_2S.$$

A cubic foot of good gunpowder should weigh about 58 pounds; 2 ounces of it when exploded in a mortar 8in. diameter, and placed at an angle of 45°, should throw a 68 pound shot about 270 feet.

181. Chlorate of Potassium, $KClO_3$ = 122.5; Sp. Gr., 1.98. This is obtained by the method described (*Par.* 65). A more economical method is to pass chlorine into a mixture of milk of lime and carbonate of potassium; the result is the formation of carbonate of lime, chlorate of potassium, and chloride of potassium; by adding water, the two latter are separated from the former, and chlorate of potassium crystallizes out. This salt is the commonest source of oxygen; it fuses between 400° and 500°; soluble in 18 parts cold water, and in 2.5 boiling water; three parts chlorate and one sulphur, when rubbed in a mortar, detonate; is used chiefly for *lucifer matches* (*Par.* 109), and as an oxidising agent; *white gunpowder* is a dangerous mixture of chlorate of potassium, ferrocyanide of potassium, and sugar; used for *blasting*.

182. **Perchlorate of Potassium,** $KClO_4$. This salt forms anhydrous prismatic needles; is got as described (*Par.* 67).

183. **Chloride of Potassium,** KCl. Sp. Gr. 1.99. This is obtained from *kelp*, and is used in the manufacture of alum. May be got by dissolving potash or its carbonate in hydrochloric acid, and evaporating to dryness. It dissolves in three parts of water; a natural compound of chloride of potassium and magnesium is found near Magdeburg.

184. **Bromide of Potassium,** $K\,Br$; Sp. Gr. 2.67. This is a very soluble salt, obtained in white crystals; it is prepared by decomposing bromide of zinc, or bromide of iron, by carbonate of potassium; it may also be got by adding bromine to caustic potash, and decomposing the bromate by sulphuretted hydrogen.

$$2K\,BrO_3 + 6H_2\,S = 2K\,Br + 6H_2\,O + 3S_2.$$

185. **Iodide of Potassium,** KI. Sp. Gr., 3.05. This salt is got when caustic potash is gently warmed, and iodine added, and the solution afterwards evaporated, and carefully ignited.

$$3I_2 + 6KHO = 5KI + KIO_3 + 3H_2\,O.$$

This salt is a useful medicine; is very soluble in water; has a cooling and somewhat bitter taste.

186. **Fluoride of Potassium,** KF; Sp. Gr., 2.45. Got by neutralising hydrofluoric acid with a solution of caustic potash. This salt corrodes glass and is alkaline.

187. Sulphides of Potassium. *Protosulphide of Potassium*, KS_2. Obtained by heating in an exhausted tube sulphur and potassium. A mixture of two parts sulphate of potassium, and one lamp-black heated, yields a *pyrophorus*, which is composed of the protosulphide of potassium and charcoal. *Bisulphide of Potassium*, ($K_2 S_2$) is obtained by heating four parts potassium with three of sulphur. *Tersulphide of Potassium* ($K_2 S_3$), is got by passing the vapour of bisulphide of carbon over carbonate of potassium, at a red heat. *Liver of Sulphur* is a mixture of this sulphide with sulphate of potassium. *Tetrasulphide of Potassium* ($K_2 S_4$) is got when the vapour of bisulphide of carbon is passed over heated sulphate of potassium. *Pentasulphide of Potassium*, $K_2 S_5$ is obtained by boiling caustic potash and an excess of sulphur together.

188. Sulphite of Potassium, ($K_2 SO_3$) is formed by passing excess of sulphurous anhydride into a solution of potash.

189. Sulphates of Potassium, *Normal Sulphate of Potassium*, ($K_2 SO_4$). This is produced when sulphuric acid is added to a strong solution of potash. It has a bitter and saline taste. *Acid Sulphate*, or *Bisulphate of Potassium*, or *Hydric Potassium Sulphate* ($KH SO_4$). This remains when nitric acid is prepared from nitrate of potassium. At a red heat it gives off sulphuric acid, sulphurous anhydride, and oxygen.

190. Iodate of Potassium, $K IO_3$. Obtained in preparation of Iodide of Potassium.

191. Potassiamide is got by heating potassium is gaseous ammonia. It is an olive coloured and deliquescent substance.

192. Phosphide of Potassium, K P, is formed when phosphorus and potassium are heated out of contact of the air. It decomposes water.

193. Cyanide of Potassium, K Cy. This is prepared by heating in a crucible 8 parts anhydrous ferrocyanide of potassium, (yel. prus. of potash), and 3 dried carbonate of potassium.

$$Cy^6 FeK^4 + K_2 CO_3 = 5(K Cy) + K CyO + Fe + CO_2$$

This is a very poisonous compound; is a powerful reducing agent; is very soluble; has a pungent and alkaline taste.

194. **Cyanate of Potassium,** $K CyO$, is prepared by fusing in a crucible, cyanide of potassium and oxide of lead (litharge).

$$K\,Cy + PbO = K\,CyO + Pb.$$

It tastes like saltpetre and is anhydrous.

195. **Ferrocyanide of Potassium,** *or Yellow Prussiate of Potash,* ($K_4\,Fe\,Cy_6,\ 3H_2O$), is obtained by heating in a covered pot, 5 parts animal refuse, 2 parts *pearl ash,* and iron filings; when cold water is added, it dissolves out the salt; it forms permanent yellow octahedral crystals; it is not poisonous; has a sweetish saline taste, is a useful reagent, and is extensively used by calico printers; with ferric salts it gives *Prussian blue.*

196. **Ferricyanide of Potassium,** $K_3\,Fe\,Cy_6$, or *Red Prussiate of Potash* is got by passing chlorine through a solution of yellow prussiate; when the solution is evaporated, red prismatic crystals separate. The crystals burn with bright scintillations; are anhydrous, and require 3.8 parts of cold water to dissolve them.

197. **Silicofluoride of Potassium,** $2KF,\ SIF_4$, is formed when hydrosilicofluoric acid is added to a salt of potassium; one of the most insoluble salts of potassium.

198. **Nitrite of Potassium,** $K\,NO_2$, is a white salt got by decomposing saltpetre at a red heat, dissolving the residue, and after the undecomposed nitre has crystallized, evaporating the solution.

199. **Silicates of Potassium** are formed by fusing silica and potash. Used in manufacture of glass.

200. **Neutral Oxalate of Potassium.** $C\,K_2\,O_4\,.\,H_2\,O$:— Got by the neutralisation of a hot solution of oxalic acid, by carbonate of potassium. It is a transparent, crystalline, and neutral salt.

201. **Binoxalate of Potassium, or Salt of Sorrel,** $C_2\,HKO_4$: Obtained by the partial neutralisation of oxalic acid, by carbonate of potassium. Transparent crystals are formed, which redden litmus and have a sour taste.

202. Quadroxalate of Potassium, $C_4 H_3 KO_8 \,.\, 2 H_2 O$:—Prepared by saturating one part oxalic acid, with carbonate of potassium, afterwards adding three parts oxalic acid. White acid crystals are thus obtained.

203. Neutral Tartrate of Potassium, $K_2 C_4 H_4 O_6 \,.\, 2 H_2 O$:—Got by treating a solution of acid tartrate of potassium with chalk. This is a neutral, white salt.

204. Acid Tartrate of Potassium, or Cream of Tartar, $K, H, C_4 H_4 O_6$:—This is obtained from argol or crude tartar by boiling it with pipeclay and filtering. This is a white salt.

205. Tartrate of Potassium and Antimony, or Tartar Emetic, $K, Sb, C_4 H_4 O_7 \,.\, 3 H_2 O$:—Got by boiling a solution of teroxide of antimony with cream of tartar. This is a white salt with a nauseous taste.

206. Tartrate of Potassium and Sodium; Rochelle or Seignette Salt; $K, Na, C_4 H_4 O_6 \,.\, 4 H_2 O$:—Prepared by the neutralisation of cream of tartar, by carbonate of sodium. It is a crystalline body, used as an aperient.

207. Tests for Potassium and its Salts—

1. Strong alkaline reaction.
2. Brown pp. with nitrate of silver.
3. Crystalline pp. with tartaric acid.
4. Yellow pp. with platinic chloride.
5. Violet colour to a smokeless flame.

Sodium and its Compounds.

$Na = 23$; Sp. Gr. 0.972; Fusing Pt., 207°.7.

208. Sodium was discovered by Davy in 1808; got by mixing carbonate of sodium, powdered charcoal and chalk, and then heating in iron retort, when the metal distils over; it is produced more readily than potassium.

It has a bluish white colour; decomposes water, and if the water is hot, the liberated hydrogen and sodium vapour will burn with yellow flame; it is very similar to potassium; is found abundantly in nature with chlorine, forming common salt, ($Na\,Cl$); forms with acids a great variety of salts.

209. Oxide of Sodium, Soda, or Sodic or Bisodic Oxide, (Na_2O). Formed by exposing sodium to dry air or oxygen; it is a white substance like anhydrous potash.

210. Hydrate of Sodium, Sodic Hydrate, Caustic Soda, or Monosodic Oxide, ($NaHO$). Got by adding milk of lime ($Ca\,H_2\,O_2$) to a solution of carbonate of sodium; process similar to that for potassic hydrate.

It is white, deliquescent, and very alkaline; dissolves readily in water; used extensively in manufacture of hard soaps; a solution having a Sp. Gr. of 1.56 contains 41.2 p. c. anhydrous soda.

211. Chloride of Sodium, Sodic Chloride, or Common Salt, ($Na\,Cl$). Sp. Gr. 2.07. Found in sea water to the extent of 2.7 p.c., or 4ozs. per gallon; obtained in South of Europe by evaporating sea-water in shallow pools near the sea; salt thus obtained is called *bay-salt*; met with as *rock-salt* in Cheshire, Poland, Spain, &c.; near Northwich in Cheshire, two beds occur, measuring together about 60 feet in thickness, 300 yards broad, and a mile and a half long; rock-salt dissolved in water, and afterwards evaporated, yields common table salt.

Common salt has a saline taste; is anhydrous; forms colourless crystals; soluble in 2.7 parts cold water; fuses at a red heat, and is converted into vapour beyond that; generally contains chloride of magnesium and calcium, and hence deliquesces in air.

Used extensively for preparing other salts of sodium, for salting meat, domestic purposes, &c.

212. Sulphate of Sodium, Sodic Sulphate, or Glauber's Salt, $Na_2 SO_4 + 10 H_2O = 322$; Sp. Gr. Anhyd. 2.597, Crys. 1.469. This is obtained by the action of oil of vitriol on common salt.

(1). $2 Na Cl + H_2 SO_4 = Na Cl + Na H SO_4 + HCl$.

(2). $Na Cl + Na H SO_4 = HCl + Na_2 SO_4$.

May be got anhydrous by heating ordinary salt on a sand bath. A third form contains 7 parts of water. The common sulphate is slightly purgative; its taste is saline; contains 55.91 per cent. of water, 24.84 of acid, 19.24 of soda; 8 parts common sulphate, and 5 of hydrochloric acid form a freezing mixture; a boiling saturated solution may remain uncrystallized several weeks, if air is excluded whilst cooling, but when poured out, it suddenly congeals; carbonate of sodium is manufactured from impure sulphate known as *salt-cake.*

213. Acid Sulphate of Sodium, $NaH SO_4$. Got by adding sulphuric acid to hot solution of sulphate of sodium.

214. Carbonate of Sodium, or Sodic Carbonate, $Na_2 CO_3, 10H_2O = 286$; Sp. Gr. Anhyd. 2.509, Crys. 1.454. Composition of 100 parts dry, Na_2O, 58.49, CO_2, 41.51; Crys. H_2O, 62.93, Na_2O, 21.68, CO_2, 15.39.

This is manufactured from sulphate of sodium, 3 parts sulphate of sodium, 3 chalk and 2 of coal are mixed; a charge of 2½ to 5 cwts. is thrown into a reverberatory furnace, and stirred until completely melted; this, when drawn out, forms *ball soda*, containing 20 to 27 p. c. of soda; the ball soda is digested for about 6 hours with water not exceeding 110° temperature; the solution is afterwards evaporated, and the residue roasted with 1-7th its weight of sawdust, when the sulphur escapes as sulphurous anhydride; this is again dissolved, and furnishes the crystallized carbonate of commerce; it contains about 56 p. c. of caustic alkali. The reaction in this manufacture may be represented by this equation:—

$$Na_2 SO_4 + 2C_2 + Ca CO_3 = CaS + 4CO + Na_2 CO_3$$

It generally contains sulphuric acid and chlorine; it is alkaline; has a disagreeable taste; very soluble in water; melts at a red heat.

215. Acid Carbonate of Sodium, or Bicarbonate of Soda, $Na H CO_3 = 84$; Sp. Gr. 2.192.

Got by passing carbonic acid into a strong solution of neutral carbonate.

$$Na_2 CO_3, 10H_2 O + CO_2 = 2(Na H CO_3) + 9(H_2 O)$$

It forms rectangular four-sided prisms, requiring 10 parts of water for solution.

216. Sesquicarbonate of Sodium, $2Na_2 CO_3, H_2 CO_3, 3H_2O = 328$.

Found on borders of lakes in Egypt and some other countries, and commonly called *trona*, or *natron;* is slightly alkaline; more soluble than bicarbonate, but not so much so as carbonate.

217. Phosphate of Sodium.—Normal Tribasic, $Na_3 PO_4 + 12H_2 O = 380$; Sp. Gr. Crys. 1.622.

Obtained from rhombic phosphate by making a solution of it, and adding caustic soda until it is soapy; crystals are formed in the liquid in small prisms.

218. Rhombic Phosphate of Sodium, $Na_2H\ PO_4 + 12H_2O = 358$; Sp. Gr. Crys. 1.586.

This is best procured by neutralizing the acid phosphate of calcium, with carbonate of sodium; the clear liquid is removed and furnishes crystals, having the form of large rhombic prisms. The crystals are alkaline to test paper and dissolve in 4 parts cold water; has a slightly saline taste; gives a yellow pp. with nitrate of silver.

219. Borax, Acid Borate of Sodium, or Biborate of Sodium, $Na_2O,\ 2B_2\ O_3,\ 10H_2O = 382$; Sp. Gr. fused 2.367, Crys. 1.740; Composition, *dry* Na_2O, 30.7, B_2O_3, 69.3 p. c.; crys. Na_2O, 16.23; $B_2\ O_3$, 36.65; H_2O, 47.12 p. c.

This salt was largely imported from India under the name of *tincal;* is now manufactured by heating crude boracic acid with half its weight of carbonate of sodium. It has a somewhat alkaline and cooling taste; it crystallizes in transparent prisms which are slightly efflorescent; dissolves in 2 parts of boiling and 12 cold water; it loses its water of crystallization when heated; at a red heat it becomes a transparent glass, which dissolves many metallic oxides; the borax *bead* is coloured blue by cobalt, violet by manganese, and green by iron, copper, and chromium; is used in *soldering*, and in the preparation of *glazes* for earthenware.

220. Nitrate of Sodium, or Cubic Nitre, $Na\ NO_3 = 85$; Sp. Gr. 2.26. Occurs a few feet below the soil in the district of Atacama in Peru; may be obtained by neutralizing carbonate of sodium with weak nitric acid. It is soluble in three parts of water at 60°; forms obtuse rhombohedra crystals; is used in manufacture of nitric and sulphuric acids, and in preparation of fireworks.

221. **Sulphite of Sodium,** $Na\ SO_3, 7H_2\ O = 252$; Sp. Gr. 1.736. Obtained by exposing moistened crystals of carbonate of sodium to sulphurous anhydride, and then dissolving in water, when the sulphite crystallizes out.

$$Na_2\ CO_3 + H_2\ O + SO_2 = Na_2\ SO_3 + H_2\ O + CO_2$$

It forms oblique prisms; it is soluble in 4 parts cold water; has a sulphurous taste and smell, and reddens vegetable blues.

Acid Sulphite of Sodium ($NaH\ SO_3$) may be got in a crystalline form.

222. **Hyposulphite of Sodium,** $Na_2\ S_2\ H_2\ O_4$, $4H_2\ O$. Got by boiling sulphite of sodium with sulphur.

$$Na_2\ SO_3 + S + H_2\ O = Na_2\ S_2\ O_3 + H_2\ O.$$

It is a white neutral salt; is very soluble in water; dissolves iodine; is used as a fixing agent in *photography.*

223. **Sulphides of Sodium.** There are 5 sulphides, which are obtained by similar methods as sulphides of potassium.

224. **Acetate of Sodium,** $Na\ C_2\ H_3\ O_2 + 3H_2\ O$. Obtained by adding acetic acid to solution of carbonate of sodium. It is a white neutral salt; is used as a reagent.

225. **Iodide of Sodium,** $Na\ I$. Occurs in sea water; obtained from *kelp,* the ashes of marine plants.

226. **Bromide of Sodium,** $Na\ Br$. This is similar to bromide of potassium; it is soluble in water and alcohol.

227. **Tribasic Phosphate of Sodium, Ammonium and Hydrogen, or Microcosmic Salt,** NaH_4, NH, PO_4, $4H_2\ O$. Got by mixing with hot solution of 6 parts phosphate of sodium, a solution of 1 part chloride of ammonium. It is used as a flux for blow-pipe experiments

228. **Carbonate of Sodium and Potassium,** $K\ Na\ CO_3$, $6H^2O$. Got by fusing the component salts.

229. **Sulphate of Potassium and Sodium,** $Na\ K_3\ 2SO_4$. Obtained by dissolving the component salts in water and evaporating. It is anhydrous; is found on sides of crystallizing vats in manufacture of iodine.

Silicates of Sodium. (*See Glass, Par.* 133, *&c.*)

230. **Tests.**—1. The presence of sodium is shown when there is a residue on evaporating a liquid, in which it has been

found that no other metal exists, and when this residue yields yellow crystals, with perchloride of platinum.

2. Bimetantimoniate of potassium when freshly prepared gives pp.

3. Blowpipe flame intensely yellow.

Lithium, and its Compounds.

$L = 7$; Sp. Gr., 0.593; Fusing Pt. 356°.

231. Lithium has not been long known; it is found in nature with alumina, silica, &c., in these minerals, *lepidolite*, *triphane*, and *petalite*. It is obtained from its chloride by electricity. It is the lightest solid known. It is harder than potassium, and has a white colour.

232. Compounds of Lithium—

Lithia	L_2O
Chloride of Lithium	$L\,Cl, 2H_2O$
Sulphate of Lithium	$L_2\,SO_4, H_2O$.
Phosphate of Lithium	$L_3\,PO_4$
Carbonate of Lithium	$L_2\,CO_3$

233. *Tests.*—1. Gives a white pp. with Carb. of Potassium.
2. Gives a pp. with Phosphate of Sodium.
3. Purplish red colour to blowpipe flame.

Ammonium, and its Compounds.

234. Ammonium is an hypothetical compound represented by $H_4\,N$. When a strong solution of sal ammoniac (chloride of ammonium) is added to potassium or sodium amalgam, the mas swells out to 8 or 10 times its original bulk, retaining its metallic appearance. This substance will crystallise at 0°F. It is generally believed that this body is a compound of mercury and ammonium. (H_4N). The salts of ammonia are understood to consist, not of *gaseous ammonia*, but of this body in combination with an *oxyacid*, or a *halogen*. (*See par.* 21 & 27.)

235. Chloride of Ammonium, H_4NCl. Sp. Gr. 1.57. Mol Vol. of Vapour ⊞. This is usually called *Muriate of Ammonia*, or *Sal Ammoniac*. It was formerly obtained in Egypt by distilling camel's dung. It is now procured from gas works chiefly, being furnished abundantly by neutralizing the *ammoniacal liquor* with hydrochloric acid. The liquid is then evaporated, after which it yields rough crystals. These crystals are then sublimed in an iron pot, when the salt is deposited on the cover in octahedral crystals.

Properties.—This salt has a sharp taste; is very soluble in water; the crystals are tough and fibrous; is frequently used in freezing mixtures; it sublimes when heated without decomposition; is anhydrous; used in tinning, dyeing, &c.

236. Sulphate of Ammonium, $(H_4N)_2SO_4$. Sp. Gr. 1.69. This salt is got by distilling gas liquor, and condensing the ammonia which is given off, in sulphuric acid. It is also readily furnished by adding sulphuric acid to sesquicarbonate of ammonium. It forms flattened prisms; has a sharp taste; is soluble in twice its weight of cold water; heated to between 500° and 600° it is partially decomposed, yielding sulphite of ammonium. It has been used of late to render muslins, &c. non-combustible; for this purpose they are dipped in a solution containing 10 per cent. of the salt.

237. There is an **Acid Sulphate of Ammonium**, $[(C_4 N)_3 H\ 2SO_4]$; also a **Double Sulphate of Sodium and Ammonium** $(H_4 N Na SO_4, 2H_2O)$.

238. Nitrate of Ammonium, $H_4 N NO_3$. Sp. Gr., 1.63. This salt is furnished by adding nitric acid to sesquicarbonate of ammonium. It has a bitter taste; in dissolving, it occasions a great fall in temperature, and hence is used for freezing mixtures; melts at 226°; at 480° is decomposed, yielding nitrous oxide and water; soluble in less than its own weight of water.

239. Sesquicarbonate of Ammonium, $2[(H_4N)_2 CO_3] CO_2$. This is the *smelling salts* of commerce. It is prepared by heating to redness one part chloride or sulphate of ammonium, and two of chalk; after water and ammonia have been disengaged, the sesquicarbonate distils over and solidifies in the neck of the retort:—

$$6H\ NCl + 3Ca\ CO_3 = 3Ca\ Cl_2 + 2[(H_4 N)_2\ CO_3\ ]\ CO_2 + 2H_3\ N + H_2\ O.$$

This is a fibrous substance, having a caustic taste, and strong ammoniacal smell; is converted into the acid carbonate by exposure to air; it is very volatile and strongly alkaline.

240. Acid Carbonate, or Bicarbonate of Ammonium, $H_4N\ HCO_3$; Sp. Gr. 1.58. This salt is got from the *sesquicarbonate* by heating it with boiling water, then corking the vessel and leaving it to stand. It forms large crystals belonging to the right prismatic; is soluble in 8 parts of cold water.

241. Normal Carbonate of Ammonium, $(H_4 N)_2 CO_3$. This salt has never been isolated; its aqueous solution may be got in combination with the acid carbonate.

242. Protosulphide of Ammonium $[(H_4 N)_2 S]$. The existence of this is doubtful.

243. Bisulphide, or Disulphide of Ammonium. $(H_4 N)_2 S_2$ may be obtained in large yellow crystals, when sulphur and dry ammonia are passed through a red-hot porcelain tube. The *Fuming Liquor* of *Boyle* is obtained by distilling 1 part sulphur, 2 parts sal ammoniac, and 2 to 3 parts quick lime. There are several other Sulphides of Ammonium :—

Trisulphide $(H_4N)_2S_3$	**Tetrasulphide** $(H_4N)_2S_4$
Pentasulphide $(H_4N)_2S_5$	**Heptasulphide** $(H_4N)_2S_7$

244. Nitrite of Ammonium, $H_4N\ NO_2$. Obtained by double decomposition of nitrite of lead, and sulphate of ammonium. Heat decomposes it into nitrogen and water.

245. Normal Acetate of Ammonium, $H_4N, C_2H_3O_2$, is got by saturating glacial acetic acid with ammonia.

246. Acid Acetate of Ammonium, $H_4N, C_2H_3O_2 + C_2H_4O_2$ is prepared when chloride of ammonium is treated with an equal weight of acetate of potassium.

247. Normal Oxalate of Ammonium, $(H_4N)_2C_2O_4 + H_2O$. Prepared by neutralising oxalic acid with ammonia. It forms long prisms which are soluble in 3 parts of cold water.

Acid Oxalate $(H_4N, HC_2O_4 + H_2O)$ is got in crystals, by adding oxalic acid to a solution of the *Normal* salt, and **Quadroxalate** is procured by crystallising a solution of equal parts of oxalic acid and *acid oxalate.*

Tests. See Ammonia, *Par.* 43.

Rubidium, and its Compounds.

248. Rubidium, (Rb = 85.36; Sp. Gr., 1.52,) was discovered in 1860 by Bunsen and Kirchhoff; is found in small quantities in *lepidolite*, in certain mineral springs, beet-root, tobacco, &c.; it is precipitated with cæsium from solutions containing it, by perchloride of platinum; the chlorides are then converted into sulphates, and reduced to the caustic state by baryta water; with carbonate of ammonium they are formed into carbonates, and cæsium is separated from rubidium as carbonate, by boiling alcohol. Rubidium is a silver-white metal; soon tarnishes in air, forming a blue suboxide; burns like potassium when thrown on water; at 14° it is soft; it melts at 101°.3.

249. Compounds of Rubidium :—

Rubidia or Protoxide of Rubidium		Rb_2O.
Chloride of	„	$Rb\ Cl$.
Sulphate of	„	$Rb_2\ SO_4$
Nitrate of	„	$Rb\ NO_3$
Carbonate of	„	$Rb_2\ CO_3$.

250. Tests.—Similar to those of potassium. 1. The chloride of Rb. and Pt. is less soluble than the chloride of K. and Pt.

2. In the spectroscope it shows two characteristic lines in the *red*, and two in the *blue*.

Cæsium, and its Compounds.

251. Cæsium, (Cs = 133,) was discovered by Bunsen and Kirchhoff at the same time as rubidium; a ton of Durckheim water yielded 3 grains of Chloride of Cs.; this metal is obtained with rubidium as described in the preceding par. This metal decomposes water setting free hydrogen.

252. Compounds of Cæsium :—

Cæsia		Cs_2O.
Chloride of Cæsium		$Cs\ Cl$.
Sulphate of	„	$Cs_2\ SO_4$.
Nitrate of	„	$Cs\ NO_3$.
Carbonate of	„	$Cs_2\ CO_3$.
Chloride of Pt. and Cæsium		$2Cs\ Cl,\ Pt\ Cl_4$

253. Test.—Only distinguished from rubidium and potassium, by 2 greyish blue lines in spectrum, from which the metal derives its name.

Barium, and its Compounds.

254. Barium, (Ba = 137; Sp. Gr. 1.5) was first obtained by Davy, in 1808, by electric decomposition of its oxide; may also be prepared by passing the vapour of potassium over red hot baryta in an iron tube; and then extracting the barium by mercury. It melts below red heat; is yellowish white; oxidises on exposure to air; decomposes water rapidly at common temperatures, and glass at a red heat; it burns with a red light when gently heated.

255. Baryta, Oxide of Barium or Baric Oxide. Ba O. This is got by exposing the pure nitrate of barium to a red heat in a large crucible;

$$Ba(NO_3)_2 = BaO + N_2O_3 + O_2$$

May also be obtained by heating the artificial carbonate of barium to a white heat. It is a grey porous body, having Sp. Gr. of 5.4; very poisonous; strongly alkaline; it readily absorbs water, forming a white hydrate, and giving off great heat.

256. Hydrate of Barium or Baric Hydrate, (BaO, H_2O). Obtained from sulphide of barium by boiling its solution with oxide of copper—

$$6BaS + 6H_2O + 8CuO = 5(BaO\ H_2O) + BaS_2H_2O_4 + 4Cu_2S.$$

May also be got, by adding an equivalent quantity of nitrate of barium to a boiling solution of caustic soda, of Sp. Gr. 1.12.

The crystals dissolve in 20 parts cold, and 3 parts boiling water; they contain 8 parts of water, and hence are represented by $BaO\ H_2O, 8H_2O$;

by heat the 8 parts of water may be expelled; the crystals and solution absorbs carbonic acid from air.

257. Peroxide of Barium, Binoxide of Barium, or Bario Peroxide BaO_2. Procured by passing oxygen over anhydrous baryta, or by heating together 1 part chlorate of potassium and 4 baryta—

$$3BaO + KClO_3 = KCl + 3BaO^2.$$

When anhydrous it is grey; put in cold water it becomes white; does not give out heat but combines with 6 parts of water, $BaO_2\ 6H_2\ O$; it (BaO^2) burns with greenish flame when heated in hydrogen.

258. Sulphide of Barium or Bario Sulphide, BaS. It may be obtained by mixing the powdered sulphate of barium with $\frac{1}{10}$ its weight of powdered charcoal, and a little oil forming a paste, then heating in a crucible for an hour.

$$Ba\,SO_4 + 4C = BaS + 4CO.$$

It forms hydrated crystals; is very soluble in hot water; absorbs oxygen and carbonic acid from air, forming carbonate and hyposulphite of barium.

259. Other Sulphides of Barium;—Hydrated Sulphide of Barium $Ba_2\,S\ .\ 3H_2\,O$; **Sulphydrate of Barium,** $Ba\,HS$; **Trisulphide of Barium,** $Ba_2\,S_3$; **Pentasulphide of Barium,** $Ba_2\,S^5$.

260. Chloride of Barium $Ba\,Cl,\ 2H_2O$. This is prepared either from the natural sulphate, or carbonate of barium; if from heavy spar, (the sulphate) 2 parts of that mineral are heated to redness, with 1 part chloride of calcium for an hour,

$$Ba_2\,SO_4 + 2Ca\,Cl = Ca_2\,SO^4 + 2Ba\,Cl;$$

the chloride is separated by dissolving the mass with hot water and filtering.

A solution of this salt of barium is commonly used to test for sulphuric acid; it gives with that acid, or solutions containing it, an immediate pp. insoluble in nitric acid.

261. Silicofluoride of Barium, $Ba\,F_2,\ Si\,F_4$. This is got on adding to a salt of barium, silicofluoric acid. Ignition decomposes it.

262. Sulphate of Barium, $Ba\,SO_4$; Sp. Gr. 4.59. This is the commonest mineral of barium, and is generally known as *heavy spar;* it is obtained when chloride of barium is added to a solution of a *sulphate*. It is insoluble in water, and acids; is used as a *permanent white* by artists; used also to adulterate white lead.

263. Carbonate of Barium, $BaCO_3$. Sp. Gr. 4.4. This is obtained when the carbonate of ammonium is added to solution of salts of barium; *Witherite* is the native carbonate of barium, found with lead in north of England, &c.

The salt is prepared on a large scale from the sulphate, which is reduced to sulphide by ignition with charcoal; the sulphide is dissolved, and decomposed by carbonic acid. It is a white powder, thus obtained, and has no alkaline reaction on vegetable colours. It is used in the manufacture of glass. It is poisonous, and very slightly soluble in water.

264. Nitrate of Barium, $Ba\,2NO_3$, Sp. Gr., 3.28. This is prepared by adding dilute nitric acid to native carbonate. It crystallizes in anhydrous octohedra; has a pungent taste: 12 times its weight cold, and 4 boiling water dissolves it; a tolerably strong solution added to nitric acid gives a pp. of the salt; it decrepitates when first heated, and afterwards fuses.

265. Green Fire is obtained by mixing 40 parts nitrate of barium, 13 flowers of sulphur, 5 chlorate of potassium, and 4 sulphide of antimony, all in fine powder.

266. Other Compounds of Barium; Bromide of Barium $BaBr$; **Iodide of Barium** BaI; **Fluoride of Barium** BaF; **Oxysulphide of Barium,** $Ba_4SO \cdot 10H_2O$; **Phosphide of Barium** BaP ?; **Selenide of Barium** Ba_2Se; **Baryto-calcite** $BaCaCO^3$.

267. Tests, &c., of Barium and its Salts:—

1. A white pp. with alkaline carbonates, and bicarbonates.
2. A white, insoluble pp. with sulphuric acid, and soluble sulphates.
3. A white pp. with an alkaline hyposulphite.
4. A white pp. with phosphate of sodium.

5. A yellowish-white pp. with chromate of potassium.

6. No pp. with oxalic acid.

7. A pp. with silicofluoric acid, distinguishing it from *Strontia.*

8. A yellowish-green flame.

9. In spectroscope, the spectrum presents bright bands in green, and fainter bands in the red.

All the soluble salts are powerful poisons, and have an unpleasant taste; sulphate of sodium, or magnesium is an antidote.

Strontium, and its Compounds.

268. Strontium, (Sr = 87.5; Sp. Gr., 2.54) derives its name from Strontian in Argyleshire, where the carbonate was first found. It is not so abundant as barium. The native compounds, most commonly met with, are the *carbonate* and *sulphate.* The metal is obtained by electrolysis from the fused chloride, iron being used for poles of the battery. It has a grey colour; is malleable; burns in air with crimson flame; it decomposes water, giving off hydrogen; is oxidised in air.

269. Strontia, or Protoxide of Strontium, SrO, Sp. Gr. 4.61. Got from the nitrate by ignition. Slakes when mixed with water, forming a hydrate, $SrO, H_2O . 8H_2O$; the 8 parts of water may be expelled by heat; heat does not drive off the remaining atom of water; the hydrate and its solution absorb carbonic acid from air. No peroxide of strontium can be obtained,

270. Nitrate of Strontium, $Sr_2 NO_3$; Sp. Gr. 2.85. (anhyd.) This is procured from native sulphate, by heating it with charcoal; the sulphide, thus formed, is dissolved in water, and decomposed by nitric acid; this salt is soluble in 5 parts cold water. Used for *red fire*, which consists of 40 parts fused nitrate, 13 powdered sulphur, 5 chlorate of potassium, and 4 sulphide of antimony. The chlorate and sulphide should be separately pounded; it is a dangerous compound, having sometimes ignited spontaneously.

271. Sulphate of Strontium, $Sr\ SO_4$; Sp. Gr. 3.9. This is a native compound called *celestine*, having a blue tint; found with rhombic prisms like sulphate of barium; the best specimens of celestine are found with sulphur in Italy. 1 part of this salt requires 3,600 of water to dissolve it; slowly soluble in chloride of sodium solution.

272. Chloride of Strontium, $Sr\ Cl_2 . 6H_2O$.; Sp. Gr. 1.6, (cryst). This is procured by dissolving carbonate of strontium in hydrochloric acid, evaporating and fusing the residue. A moderate heat renders it anhydrous; is soluble in alcohol; of a grey colour and burning taste.

273. Carbonate of Strontium, $Sr\ CO_3$; Sp. Gr. 3.65. The native compound, *Strontianite* is found near Strontian, in Argyle. It has a greenish tint, and is found in radiated masses. May be artificially prepared by precipitating a salt of strontium, with the carbonate of an alkali. The salt is decomposed by ignition; it is dissolved by a solution of carbonic acid.

274. Tests, &c., of Strontium and its Salts:—

1. Sulphuric Acid gives a pp. *slowly*.

2. Neither silicofluoric acid nor hyposulphite of sodium gives a pp.

3. Red flame before blow-pipe, or in Bunsen's burner.

4. Eight bright bands in blue, red, and orange, part of spectrum.

The above distinguish strontia from baryta.

5. Oxalic acid gives slowly a pp.

The salts of strontium are not poisonous; have a burning bitter taste, and with colourless acids are colourless.

Calcium, and its Compounds.

275. Calcium, (Ca = 40; Sp. Gr. 1.578) is found abundantly in nature, forming with oxygen the well-known mineral *lime.* It is obtained from the chloride of calcium by *electrolysis,* using iron poles with the battery. It is a light, yellowish metal, harder than lead, malleable, fusible at a red heat, and is slowly oxidised in humid air. Burns when heated to redness with white light. First shown to be the base of lime, by Davy, in 1808.

276. Lime, Oxide of Calcium, or Quicklime. CaO; Sp. Gr., 3.18. This is the only oxide of calcium; is obtained pure by exposing the carbonate, or nitrate to white heat for an hour. Pure lime is white, caustic and alkaline. It is infusible, but promotes the fusion of other oxides; is remarkably luminous when heated by oxyhydrogen blowpipe; absorbs moisture and carbonic acid from air, hence a useful *dehydrating* agent.

277. Lime Burning :—Lime is commonly obtained by burning *limestone,* which is the natural carbonate of calcium, in a large cup-shaped kiln; layers of limestone and coal are placed in the kiln, and the fire is kindled; as the lime is burnt it is removed from the bottom, whilst alternate layers of coal and limestone are supplied at the top. This method, called the *continuous* process, has superseded the old one of renewing the charge every 3 or 4 days.

278. Hydrate of Lime, or Slaked Lime, CaO, H_2O. Sp. Gr. 2.07. This is formed when water is added to *quicklime;* the increase in bulk and rise in temperature is occasioned by the *combination* of the water with the lime; the heat developed in slaking large heaps of lime is sometimes sufficient to scorch wood. Lime exposed to air absorbs water and carbonic acid, and falls to powder, thus becoming *air slaked;* it is believed by some to have under these circumstances this composition, $CaO, CO_2 . CaO, H_2O$.

279. Lime-water is obtained by dissolving quicklime in *cold* water; 750 parts of water dissolve 1 of lime; if lime-water be boiled, half the lime will be deposited, shewing that lime is more soluble in cold than hot water. This solution is a good test for carbonic acid; by mere exposure to air a pellicle of carbonate of lime is formed.

280. Milk of Lime is water containing the hydrate of lime in suspension.

281. Mortars. These are composed mainly of lime and silica. Mortar absorbs carbonic anhydride from the air, and at the same time the lime gradually combines with the silica, forming a silicate of lime; these facts, it is thought account for the hardening of mortars.

282. Hydraulic Cements. These are such *cements* as harden in water. They are prepared in a variety of ways; *meagre* limes, containing clay, afford such a cement when burnt; 4 parts chalk, ground in water with 1 part clay, and afterwards dried, and calcined also yield such a cement. The hardening seems to depend on the formation of a hydrated compound of lime, with the silica and alumina. **Portland cement** is made from clay and chalk, and has the appearance of Portland stone. **Roman cement** is obtained from stones, or nodules called *Septaria*, found near the Thames, and containing 36 per cent. clay, and 8.6 oxide of iron. **Puzzuolana** is a volcanic product, found at Puzzuoli, near Naples; it contains silicates of alumina, lime, and soda, and when mixed with lime, forms an excellent hydraulic mortar. **Concrete** consists of hydraulic mortar and small pebbles.

283. Uses of Lime. Besides its use for mortars, it is a valuable manure, especially in soils containing much vegetable matter; it destroys an excess of organic matter, and sets free potash for support of plants; it is used also for drying certain gases and absorbing water from alcohol.

284. Sulphides of Calcium. Protosulphide of Calcium is got by exposing sulphate of lime and charcoal to red heat. It is slowly acted on by water; when newly prepared is phosphorescent (Canton's phosphorus). **Pentasulphide** is obtained by boiling slaked lime with excess of sulphur:—

$$3CaO + 12S + H_2O = 2CaS_5 + CaS_2H_2O_4.$$

285. Phosphide of Calcium, CaP?; this is got when phosphorus vapour is passed over red hot lime.

$$7P + 7CaO = Ca_2P_2O_7 + 5CaP.$$

It is a brown substance which decomposes water when thrown into it, giving off phosphuretted hydrogen.

286. Chloride of Calcium, or Muriate of Lime $CaCl_2 . 6H_2O$. Sp. Gr. *fused* 2.48. Procured by dissolving chalk in hydrochloric acid. It deliquesces rapidly in air, and is often used after fusion to remove watery vapour from gases; has a bitter taste.

287. **Oxychloride of Calcium** is prepared by boiling the chloride with quicklime, and filtering whilst hot. Its formula is $CaCl_2\ 3CaO\ .\ 15H_2O$.

288. **Chloride of Lime.** This bleaching material is obtained by passing chlorine into chambers containing hydrate of lime in fine powder. See *Bleaching, Par.* 61. Its composition is supposed to be $Ca\ Cl_2\ Ca\ 2ClO$.

289. **Fluoride of Calcium, or Fluorspar,** $Ca\ F_2$. Sp. Gr. 3.14. This occurs abundantly in the lead mines of Derbyshire, Cumberland, &c., and is called *blue John.* It is most frequently found of a blue, green, or white colour; the blue varieties become red, and brown by heat; when gently heated, the mineral becomes phosphorescent. The artificial compound may be prepared by saturating hydrofluoric acid with carbonate of lime.

290. **Sulphate of Calcium,** $Ca\ SO_4$; Sp. Gr. 2.95. *Native Sulphates :—Anhydrite,* containing no water; the hydrates containing two atoms of water, as *alabaster, gypsum* and *selenite.* Obtained *artificially,* when a salt of calcium in solution is precipitated by sulphuric acid. It requires 400 parts of water to dissolve it. Heated to 300°, it loses 20 per cent. of water, and forms *plaster of Paris;* plaster of Paris mixed with size and water, hardens, and hence is used for artificial marble, stucco, busts, figures, &c.; sulphate of calcium is often found in spring water, and forms an incrustation in boilers, having the compositon $2(CaSO_4)\ H_2O$.

291. **Carbonate of Lime,** or Carbonate of Calcium. $Ca\ CO_3$. Sp. Gr. of *Iceland Spar* 2.72. This is found very

abundantly in nature. It is found in all fertile soils, and in spring and river water. The following are some of the native carbonates:—*Chalk*, *Iceland Spar*, *Calcareous Spar*, *Stalactites*, *Stalagmites*, *Satin Spar*, *Marble*, *Oolite*, *Portland Stone* and *Arragonite*. The salt is got by precipitating any of the soluble salts of lime with an alkaline carbonate. It is a tasteless white powder, having no alkaline reaction.

292. Hardness of Water. When water contains a considerable quantity of carbonate of lime in solution, it is *temporarily hard*. The lime is deposited in kettles and boilers forming a hard incrustation. This form of hardness may be prevented by adding soda-ash, or sal-ammoniac to the water. When water contains a large amount of free carbonic acid in solution, it dissolves carbonate of lime more freely, if lime therefore is added to such water, it neutralises the carbonic acid, and the carbonate previously in solution, is precipitated.

293. Clark's Soap-Test;—A grain of chalk in a gallon of water represents 1° (*degree*) of hardness. The number of grains of any salt of calcium in a gallon of water is said to represent so many *degrees* of hardness. The number of degrees is determined by adding a solution of soap, made of a definite strength, until it gives a permanent lather.

294. Phosphates of Calcium. Of these the most important is *Bone or Tribasic Phosphate*, $Ca''_3\ 2\ PO_4$. It forms the principal constituent in bone ash. When chloride of calcium is added to a solution of phosphate of sodium, this compound is obtained with $2H_2O$. It is insoluble in water.

This phosphate occurs in *apatite*, *moroxite*, *phosphorite*, *coprolites* and *asparagus stone*. It is found in all fertile soils, and in the vegetables they produce.

295. Other Compounds of Calcium, Silicide of Calcium, Si_2Ca; **Superbosphate of Lime,** $Ca'' H_4 2PO_4$, **Double Borate of Calcium and Sodium,** $[2(Na\,Ca\,3BO^2)\,3B_2O_3 . 18H_2O]$; **Oxysulphide of Calcium,** $Ca^{12}S^5O + 20H_2O$; **Iodide of Calcium,** $Ca\,I$; **Bromide of Calcium,** $Ca\,Br$; **Sulphite of Calcium,** $Ca\,SO_3$; **Silicate of Calcium,** (Wollastonite) $Ca\,SiO^3$.

296. Tests, &c., of Calcium and its Salts :—

1. Precipitated by alkaline carbonates, and bicarbonates.
2. *Not pp.* by sulphuric acid, or alkaline sulphates, unless strong solution.
3. Sulphate of calcium gives *no* pp.
4. Precipitated by oxalic acid, and oxalate of ammonia. This last reagent will detect 1 part of lime in 50,000 of water.
5. Greenish-yellow tinge to flame.
6. In spectroscope, (a) bright line in orange, (b) broad band in green, (c) faint lines in red, and (d) occasionally a bright blue band.

Aluminum, and its Compounds.

297. Aluminum, $Al = 27.5$; Sp. Gr. 2.5 to 2.6, may be obtained by passing the vapour of chloride of aluminum over sodium heated in a porcelain tube (Deville). *Cryolite* ($3NaF, AlF_3$) has been used as a source of this metal, in which case, the powdered mineral is mixed with half its weight of common salt, and the mixture is arranged in alternate layers with sodium in a crucible, a layer of cryolite being placed at the top, and the whole covered with common salt. It is rapidly heated; on cooling, the metal is found in globules. It is a white malleable metal, about as hard as silver; hydrochloric acid acts readily on it; not affected by sulphuretted hydrogen; may be drawn into fine wire; solutions of the alkalies oxidise the metal, and hydrogen is given off; may be alloyed with copper, giving a hard compound, varying in colour with proportions of the metals; one of these with 10 per cent. aluminum, has a beautiful golden colour, and is known as *aluminum bronze.*

298. Alumina, or Oxide of Aluminum, Al_2O_3. This is the only oxide of aluminum at present known; got by igniting ammonia alum ($H_4N\ Al\ 2SO_4 . 12H_2O$), or by precipitating common alum by carbonate of potassium, washing the pp., redissolving in hydrochloric acid, and precipitating with ammonia. A white gelatinous hydrate is obtained, which by heating, may be rendered anhydrous. This oxide with silica forms *clay*. Native alumina occurs in the *sapphire, ruby, topaz, corundum, adamantine spar, emery,* and *diaspore.*

Uses.—Alumina has a great affinity for colouring matter, hence when cloth has been soaked in some solution of a salt of aluminum, the earth adheres to it, and when it is afterwards plunged into a bath of dye liquor, the colour is fixed. Bodies which thus fix colour, are called *Mordants.* Ammonia added to a solution of alum in infusion of cochineal, or madder, precipitates alumina in combination with colouring matters, forming *lakes.*

299. Aluminate of Sodium, $Na_3\ AlO_3$. When *Bauxite* (aluminous peroxide of iron) is heated with carbonate of sodium, and afterwards lixiviated, this salt is dissolved out, and is obtained as a whitish compound, by evaporation. It is used for pigments, and as a mordant.

300. Chloride of Aluminum, $Al_2 Cl_6$. This is procured as a yellow sublimate by the following process:—Alumina is mixed with powdered charcoal, and made into a paste with starch or oil; this is heated in a covered crucible, and afterwards transferred to a porcelain tube, and, whilst heated in a furnace, chlorine is passed into it. $Al_2 O_3 + 3C + 3Cl_2 = Al_2 Cl_6 + 3CO$. The salt fumes and deliquesces when exposed to air.

301. Fluoride of Aluminum is found in nature with fluoride of sodium in *cryolite* ($3NaF, AlF^3$).

302. Sesquisulphate of Aluminum, ($Al_2 3SO_4 . 18H_2O$.) is got by digesting alumina in sulphuric acid, or on a large scale, by digesting clay or shale for 3 or 4 days with sulphuric acid, then dissolving and evaporating; known as *concentrated alum.* It forms lamellar crystals, which have a sweet and astringent taste.

303. Alum, Sulphate of Aluminum, and Potassium, or Potash Alum, $KAl\ 2SO_4 . 12H_2O$. *Manufacture*:—At Whitby, and near Glasgow this salt is manufactured on a large scale, from *aluminous slate* or *shale,* found with coal, and containing bisulphide of iron; the ore is exposed to air, or slowly roasted to oxidise the iron and acidify the sulphur; by lixiviation a sulphate of aluminum is obtained, which with chloride, or sulphate of potassium yields alum.

(1). $2FeS_2 + 3O_2 = 2Fe\ S + 2SO_3$; and afterwards

(2). $FeS + 2O_2 = Fe\ SO_4$;

(3). $2KCl + FeSO_4 = Fe\ Cl_2 + K_2\ SO_4$.

Roman alum is prepared near Civita-Vecchia from *alum-stone,* by heating the stone and dissolving out the salt.

Properties.—The common alum is colourless; has a sweet and astringent taste; reddens vegetable blues; fuses when heated; when heated to dryness, known as *burnt alum,* or *roche alum;* soluble in 18 parts of water; forms large octohedral crystals.

Uses.—In dyeing, calico-printing, paper making, and also in preparation of colours; rendering wood and paper incombustible; and as a medicine.

304. Other Alums:—

Ammonium	Alum	$H_4N\ Al\ 2SO_4 . 12H_2O$.
Sodium	„	$Na\ Al\ 2SO_4 . 12H_2O$.
Lithium	„	$Li\ Al\ 2SO_4 . 12H_2O$.
Potassium	„	$K\ Al\ 2SO_4 . 12H_2O$.
Iron	„	$K\ Fe\ 2SO_4 . 12H_2O$.
Chrome	„	$K\ Cr\ 2SO_4 . 12H_3O$.
Manganese	„	$K\ Mn\ 2SO_4 . 12H_2O$.

The new alkalies Cæsium and Rubidium form alums with sulphate of aluminum.

305. Phosphate of Aluminum, $Al\ PO^4$. Got by adding phosphate of sodium to solution of alum. The pp. dries into a white insipid powder. The following minerals contain the salt, *Wavellite, Lazulite, Ambligonite, Turquoise* or *Calaite* and *Gibbsite.*

306. Silicates of Aluminum. The various kinds of clay are silicates, or *hydrated* silicates of aluminum. Common *Felspar*, which is a constituent of *granite*, is a silicate of aluminum, and potassium; by the action of air and water it crumbles into a white clay; *Cornish clay* and *Kaolin* are thus formed; *Marl* is composed of lime and clay; clay is variously coloured by the oxides of iron; the presence of lime, magnesia, or oxide of iron renders clay more fusible, or vitrifiable; *Fire-clay* is nearly *pure* silicate of aluminum; *Yellow ochre* and *Red boll* consist of clay and peroxide of iron; *Fuller's earth* is a porous silicate of aluminum; Devonshire and Dorsetshire *Blue Clay* is coloured with organic matter, which is destroyed by heating; it is used for porcelain; *Pipe-clay* is white, and nearly free from iron; it is used for tobacco pipes; *Loam* contains a variety of substances with clay; is red or brown from peroxide of iron; used extensively in *brick-making*. Clay gives off a peculiar odour when wetted or breathed on; it absorbs ammonia generated by manures, and hence its agricultural value; its *plasticity* when humid, renders it well adapted for the manufacture of pottery.

The following minerals contain silicates of alumina:—*Adularia, Albite Petalite, Labradorite, Syenite, Gneiss, Porphyry, Basalt, Dolerite, Trap, Diorite, Trachyte, Pumice-stone, Obsidian, Garnet, Pyrope, Mica, Chlorite, Roofing slate, Mica and Hornblende slate, Zeolites, Stilbite, Analcime, Prehnite.*

307. Pottery and Porcelain. In the manufacture of *porcelain*, or *china*, the principal materials used are *clay*, (chiefly from Devonshire), and *flints*—the former supplying alumina, and the latter silica. The flints are reduced to a powder by heating them to redness, then quenching them in cold water; each material being carefully powdered and sifted, is suspended in water; is mixed in measured proportions, and evaporated to due consistence for working; on the *potter's wheel* the clay is formed into the required shape; the moulded articles are next placed in a warm room to dry; handles and ornaments are now added, where necessary, and the ware is then removed to the *biscuit* furnace; after the last operation the articles, which are now called *biscuit*, are coloured or printed, the vessels readily absorbing colouring matter; they are afterwards *glazed* by dipping them into a tub containing 60 parts litharge, 10 of clay and 20 of ground flint, with water sufficient to give a creamy consistence; on further heating, the glaze melts and gives a glassy appearance to the surface of the ware. The colour for earthenware is generally a metallic oxide ground with oil of turpentine, oil of spike-lavender or boiled linseed oil; a *blue* is given by oxide of cobalt; *green*, by oxide of chromium; *brown*, by oxides of iron and manganese; *black*, by black oxide of uranium; and *pink*, by oxide of tin, lime, and oxide of chromium. Coloured patterns are first printed on thin unsized paper, and applied to the vessels whilst the colour is moist. Porcelain is gilded by applying gold in a fine powder, mixed with gum-water, and borax.

Berlin Porcelain consists of 71 silica, 24 alumina, 2 potash, 1.5 protoxide of iron, and 1.5 lime, and magnesia.

Stoneware is an inferior kind of porcelain. **Wedgewood-ware** is a better kind of stoneware. **Fine earthenware** is the common table-service of this country. **Common Earthenware** is made of more fusible clay, and cracks easily, when heat is applied.

308. Tests for Aluminum and its Compounds :—

1. Ammonia gives a gelatinous pp. of hydrate of alumina, nearly insoluble in excess of ammonia.
2. Carbonates and bicarbonates of the *alkalies* precipitate the hydrate of alumina.
3. Sulphate of potassium and sulphuric acid give crystals of alum.
4. Hydrosulphate of ammonium gives a white pp., whilst sulphuretted hydrogen is evolved.
5. Moistened with nitrate of cobalt on charcoal, before blow-pipe, a pale blue.

Salts of aluminum have an astringent and sweet taste, and redden litmus paper.

Glucinum, and its Compounds.

309. **Glucinum** ($G = 9.5$; Sp. Gr. 2.1) is prepared from its chloride by the same method as aluminum. It is found in the *Emerald* and *Beryl*, which consist chiefly of silicate of glucinum and aluminum. It is a white metal; is readily dissolved by hydrochloric and sulphuric acids, and potash.

Compounds of Glucinum:—

Glucina	GO.
Chloride of Glucinum	$G\,Cl_2$.
Aluminate ,,	GO, Al_2O_3.

310. **Tests, &c.—**

1. White pp. with carbonate of ammonium.
2. Sulphide of potassium gives a white pp.
3. Does not form an alum with the sulphate of potassium.
4. Does not give a blue colour with nitrate of cobalt.
5. When a hot solution of fluoride of potassium is added to a hot solution of glucinum salt, scales of double fluoride of potassium and glucinum are formed.

The salts have a sweet taste and are acid.

Zirconium, and its Compounds.

311. **Zirconium** ($Zr = 89.5$) has only been met with in the *Zircon* or *Jargon*, and a few other rare minerals. It is procured from the fluoride of potassium and zirconium, by potassium at a red heat. It is a black powder, having a similar appearance to plumbago.

Compounds of Zirconium:—

Zirconia	ZrO_2
Chloride of Zirconium	$Zr\,Cl_4$

312. **Tests, &c.—**

1. The salts are precipitated by caustic alkalies.
2. Give a yellow pp. with tincture of galls.
3. Form subsulphate of zirconium, when boiled with sulphate of potassium.
4. They have an astringent taste.

Thorinum, and its Compounds.

313. **Thorinum** ($Th = 119$.) is got by passing dry chlorine over a mixture of charcoal powder and thorina, and decomposing the chloride thus obtained with potassium. It has a grey colour and metallic lustre. Sulphuric acid acts slightly on it, and nitric acid scarcely at all; hydrochloric acid dissolves it. *Thorina* is supposed to be a protoxide. *Sulphate of Thorinum* has been obtained.

Yttrium, Erbium, Terbium, Cerium, Lanthanum and Didymium.

314. **Yttrrium**, Y, is obtained by decomposing its chloride by potassium; it is grey and brittle. **Oxide of Yttrium** or **Yttria**, YO, is found in *Gadolinite*.

315. **Erbium and Terbium.** *Erbia* is of a pale yellow colour, and *Terbia* a pale red. These oxides are said to always accompany *Yttria*.

316. **Cerium**, Ce, is found in a very few minerals, one of which is *Cerite*. It seems to form two oxides, the *protoxide* and *sesquioxide*. The *oxalate*, $Ce\,C_2\,O_4,\ 3H_2\,O$, has been lately used as a medicine in cases of excessive vomiting.

317. **Lanthanum**, La, is found with cerium; it forms but one oxide. Its salts are colourless.

318. **Didymium**, Di, is found with the last two metals. It forms only one oxide, which has a brown colour. The *sulphate* and *nitrate* are rose-coloured.

Magnesium, and its Compounds.

319. **Magnesium** ($Mg = 24$; Sp. Gr. 1.743) is met with abundantly in nature, forming with calcium, *dolomite*, or *magnesian limestone*. Was first procured by Davy, in 1808. It may be prepared by fusing a mixture of the pure chloride of magnesium, chloride of sodium, fluoride of calcium, and sodium, the metal is thus obtained in globules. It may

be also obtained by electrolyzing the fused chloride of magnesium. It is a silvery-white metal; malleable; slowly oxidised in damp air; burns in air with such brilliancy that it has been used in taking photographic likenesses.

320. Magnesia, or Oxide of Magnesium, $MgO = 40$; Sp. Gr. 3.6. This is the only known oxide of magnesium; is procured by heating to redness the carbonate, or nitrate of the metal. It is a bulky, white powder, without taste; it is nearly insoluble in water; has alkaline reaction on vegetable colours; forms a *hydrate* with water, $H_2 Mg O_2$.

321. Nitrate of Magnesium, $Mg\,2NO_3 . 6H_2O$. Sp. Gr. 1.4. This is a very deliquescent salt, procured by digesting carbonate of magnesia in weak nitric acid. It has a cooling and bitter taste.

322. Chloride of Magnesium, $Mg\,Cl^2$. This salt is found in sea-water. May be prepared by dissolving 1 part magnesia in hydrochloric acid, and afterwards adding 3 parts sal ammoniac; a double chloride is thus formed, which is decomposed by ignition in a crucible, leaving the above salt. It is a deliquescent salt; very soluble in water, and having a bitter taste.

323. Sulphide of Magnesium, MgS, is got by adding sulphide of potassium to a boiling solution of sulphate of magnesium.

324. Sulphate of Magnesium, $Mg\,SO_4 . 7H_2O$.; Sp. Gr. 1.6. This salt is known in commerce as *Epsom salt.* It is prepared from sea-water, and also from *magnesian limestone.* In the *former* case, after common salt is removed by crystallization, the liquid is boiled down with sulphuric acid, or the *bittern* may be decomposed by lime, and then the precipitate treated with sulphuric acid. In the *latter* case, the limestone is burnt, reduced to powder, suspended in water, and treated with sulphuric acid. It has a saline and bitter taste; at a red heat the salt becomes anhydrous; soluble in 3 times its weight of water; the crystallized sulphate loses 6 atoms of water when heated, but retains the remaining atom up to 560°; at a red heat it becomes anhydrous.

325. Carbonate of Magnesium, $Mg CO_3$.; Sp. Gr. 3.0. This is procured by the precipitation of a boiling solution of some magnesium salt, by adding carbonate of sodium or potassium. The crystals effloresce in air.

326. *Magnesia alba* is the white magnesia of commerce, and is obtained from the sulphate of magnesium, by adding a hot solution of carbonate of sodium. It is a light powder; slightly soluble in water; it is composed of hydrate of magnesia, and the hydrated carbonate, $Mg CO_3, H_2 O + Mg H_2 O_2$.

327. *Magnesite* is a native carbonate; *Dolomite* is a magnesian carbonate of calcium, $Mg Ca 2CO_3$; a pure carbonate is now made from the latter mineral; *Bitter spar* and *conite* have a similar composition to Dolomite.

328. Silicates of Magnesium. There are many native silicates of magnesium, The following is a list of several of them:—

Serpentine	$2[(Mg Fe) O, SiO_2] . MgO, 2H^2O$.
Steatite, French-chalk or Soap-stone	$MgO, SiO_2 . 2MgO, 3SiO^2$.
Meerschaum	$2MgO, 3SiO_2 . 4H_2 O$.
Talc	$2(MgO, SiO^2) 2MgO, 3SiO^2$.
Chrysolite, or Olivine	$2(Mg Fe)O, SiO^2$.
Picrosmine	$2Mg SiO_3 . H_2 O$.
Augite or Pyroxene	$(Ca Mg Fe Mn)O, SiO_2$.

Hornblende, Amphibole, or Asbestos belongs to this class of compounds,

$$3[(Mg Ca Fe)O, SiO^2] . 2(Mg Ca Fe Mn)O, 3SiO^2 . x(KCa) F_2.$$

329. Triphosphate of Magnesium and Hydrogen, or Tribasic Phosphate of Magnesia and Water, $HMg, PO^4 . 7H_2O$. This is formed when a solution of a salt of magnesium is added to one of the common phosphate of sodium. It is crystalline, and sparingly soluble in water.

330. Triphosphate of Magnesium and Ammonium, or Triple Phosphate, $Mg H_4 N, PO_4 . 6H^2O$. It is obtained when ammonia, or an ammoniacal salt is added to a mixture of a salt of magnesium, and phosphate of sodium. It is often deposited from urine, having the appearance of white sand. It may be detected in malt liquor, in the husk of grain, and in the potato, &c. It dissolves readily in acids.

331. **Borates of Magnesium.** Several have been formed. One found in Holstein called *Boracite* is the only one of interest. This is its formula, $3(Mg2BO^2)$, B_2O^3.

332. Tests, &c.:—

1. Potash and soda give a gelatinous pp. of the *hydrate.*
2. Ammonia only gives a slight pp. (chloride of ammonium will redissolve it.)
3. Lime-water gives a pp.
4. Phosphate of ammonium gives a pp.
5. The acid carbonates of the alkalies do not precipitate the salts, unless boiled.
6. Give a pink colour, when heated before blow-pipe with nitrate of cobalt.

The salts of magnesium are bitter.

Zinc, and its Compounds.

333. Zinc (Zn = 65; Sp. Gr., 6.8) of commerce is obtained from *Calamine*, the natural *carbonate*, or *Blende*, the native *sulphide.* In its manufacture, the ore is crushed into small pieces between rollers, and afterwards roasted in a reverberatory furnace, in which carbonic anhydride is driven off from the calamine, and sulphurous anhydride from the *blende.* It is afterwards ground, and mixed with one-eighth its weight of charcoal powdered, and then heated in large crucibles, placed generally in a circular furnace; to the bottom of each crucible there is attached an iron pipe, which dips into a sheet-iron vessel below containing water. On the application of a red heat, the zinc distils through the tube into the water. This method is called distillation *per descensum*. It is practised in England, but in Silesia and Belgium other methods are in use.

Zinc is a bluish-white metal; has considerable lustre; is somewhat brittle at ordinary temperatures; may be drawn out into wire; and rolled into thin leaves between 200° and 300°; is volatile at a bright red heat; gives off peculiar smell when breathed on; oxidises in moist air, when the oxide formed protects the metal beneath; heated above fusing point, it burns with greenish-white flame; in presence of acids it decomposes water.

Uses.—Used for chimney-tops, coating sheet-iron, (the iron is then said to be *galvanized)*, roofing &c., &c. One part zinc and 2 copper form *brass*; zinc in powder is used as a basis of paint.

334. Oxide of Zinc, ZnO, is prepared by heating the metal exposed to air. It is a light, white powder, which becomes yellow when heated; is insoluble in water; is used as a pigment, instead of white lead, not being injurious to the health of painters, nor affected by sulphuretted hydrogen, but it soon peels off; is used as a tonic, and as an outward application. *Tutty* is an impure oxide. Caustic potash precipitates the *hydrate of zinc* (ZnO, H_2O) from salts of zinc.

335. Chloride of Zinc, $Zn\,Cl_2$, is obtained by dissolving the metal in hydrochloric acid. It is known as *butter of zinc*. It is a white, and very deliquescent compound; is powerfully corrosive; has a nauseous taste and is a strong emetic. *Burnett's disinfecting fluid*, and preservative against *Dry-rot*, is a strong solution of this salt. Chloride of zinc and ammonium

($2H_4NCl, ZnCl_2$) is used to remove film of oxide on metals, before soldering them.

336. **Sulphide of Zinc or Blende,** or **Black-jack,** (ZnS; Sp. Gr. 4.1,) is procured by heating oxide of zinc with sulphur. This compound is an abundant mineral of zinc, and an important source of the metal. It occurs in crystals which are brittle, and of a brown, or black colour; it generally contains traces of iron and lead.

337. **Carbonate of Zinc, or Calamine,** $ZnCO_3$, Sp. Gr. 4.4, is found in nature both in the *amorphous* and *crystalline* form; no neutral carbonate can be got by double decomposition; by adding carbonate of potassium to sulphate of zinc, an oxy-carbonate of zinc is obtained $8ZnO, 3CO_2 . 6H_2O$. Calamine abounds in Somersetshire, Flintshire, and Derbyshire. *Electric calamine* consists of the oxide of zinc and silica.

338. **Sulphate of Zinc,** or **White Vitriol,** $ZnSO_4 7H_2O$., Sp. Gr. 1.9. This salt is readily obtained by adding sulphuric acid and water to the metal in the preparation of hydrogen, *See Par.* 31. It is very soluble in water; has acid reaction with test paper; the crystals are four-sided prisms; is used as a medicine, and largely in calico printing; it forms double salts with ammonium, potassium, magnesium and protoxide of iron; it is poisonous.

339. **Nitrate of Zinc,** $Zn 2NO_3 . 6H_2O$, is a deliquescent salt; is prepared by dissolving zinc in dilute nitric acid.

340. **Tests, &c.—**

1. Sulphide of ammonium gives a white *hydrated* sulphide with salts of zinc.
2. Potash, soda, or ammonia, gives a pp. of white hydrated oxide.

3. Ferrocyanide of potassium gives a white, and ferricyanide a brownish pp.
4. Carbonates of potassium and sodium give a pp., *not* soluble in excess; the pp. with carbonate of ammonium *is soluble* in excess.
5. Before the blow-pipe on charcoal, oxide of zinc becomes yellow, but on cooling is white. With nitrate of cobalt, a green residue.

Cadmium, and its Compounds.

341. **Cadmium** Cd = 112; Sp. Gr. 8.6. This metal was discovered by Stromeyer in 1818. It is found as *sulphide* in zinc ore, and is obtained in the distillation of that mineral, Cadmium first sublimes in the operation, and is separated from zinc, by dissolving in sulphuric acid, and passing sulphuretted hydrogen through the solution, which precipitates the cadmium. The sulphide thus obtained, is dissolved in hydrochloric acid, precipitated by carbonate of ammonium, and heated with charcoal, when the metal distils over.

Cadmium has the colour and physical properties of tin; is very soft, malleable and ductile; becomes brittle at 180°; fuses at 242°; air scarcely acts on it unless it is heated; it crackles when bent; it dissolves readily in weak acids; with bismuth, lead, and tin, it furnishes a silver white alloy.

342. **Oxide of Cadmium,** CdO, is procured as an *anhydrous* brown powder, by burning the metal in air, and as a *hydrate* (CdO, H_2O) by decomposing some salt, by potash or soda. The hydrate is white; the anhydrous oxide is infusible and does not volatilise.

343. **Sulphide of Cadmium,** CdS, is prepared by precipitating a salt of cadmium by sulphuretted hydrogen. It is bright yellow and furnishes a yellow paint; resembles sulphide of arsenic. There is a native sulphide called *Greenockite.*

344. **Chloride of Cadmium,** $CdCl_2 . 2H_2O$, is got by dissolving cadmium in hydrochloric acid; it readily forms prismatic crystals; which are soluble in water.

345. Iodide of Cadmium, Cd I, is obtained by digesting the metal in water, with iodine. Used for *iodizing* collodion in photography. The *Bromide of Cadmium,* Ca Br is prepared and used similarly.

346. Sulphate of Cadmium, $Cd\ SO_4 . 4H_2\ O$. May be obtained by dissolving the metal, its oxide, or carbonate in sulphuric acid; it forms prismatic crystals which are very soluble in water.

347. *Other Compounds of Cadmium:*—**Nitrate of Cadmium,** $Cd\ 2NO_3 . 4H_2\ O$; **Carbonate of Cadmium,** $Cd\ CO_3$; **Fluoride of Cadmium,** CdF.

348. Tests, &c.—

1. Sulphuretted hydrogen precipitates the yellow sulphide; insoluble in potash and ammonia, but dissolves in strong hydrochloric acid.
2. Hydrates of potash and soda throw down a white *hydrated* oxide, *insoluble* in excess.
3. Ammonia gives a similar precipitate, *soluble* in excess.
4. Carbonates of the alkalies give a white carbonate.
5. Ferrocyanide of potassium gives a yellowish white pp.
6. A ring of brown oxide on charcoal, before blow-pipe.

The salts are colourless, and similar to those of zinc.

Cobalt, and its Compounds.

349. Cobalt (CO = 59; Sp. Gr. 8.95) is met with in nature associated with arsenic as *Tin-white Cobalt* or *Smaltine* ($CO\ As_2$), or with arsenic and sulphur, as *Glance Cobalt* (CoS_2, $CoAs_2$). Iron, nickel, bismuth, and copper are commonly combined with cobalt in its ores. Cobalt is never used as a metal, so that its reduction is only carried on to a small extent. (*Par.* 361). It is very difficult to separate from the nickel. The metal has a reddish-grey colour; it is brittle, and fuses with difficulty; it is almost unalterable in air; it dissolves slowly in hydrochloric, but freely in nitric acid.

350. Protoxide of Cobalt, CoO, is obtained by adding potash to the nitrate and washing, and drying pp. out of contact of air; freshly precipitated, it is *blue*; in contact with water for a time, it becomes a *red hydrate;* heated to dull redness in air, it is *black*; more strongly heated, it is *brown;* when obtained from the carbonate, it is *greenish-grey*. *Zaffre* is an impure oxide of cobalt, having a very blue colour; it is obtained by calcining the ore. *Smalt* and *Azure blue* are got by fusing zaffre with glass; smalt is used by paper-stainers to give a blue colour. *Thénard's blue* is a compound of alumina and oxide of cobalt, having a pale blue colour. *Rinmann's green* contains oxide of zinc with cobalt; used as a pigment.

351. Hydrated Oxide of Cobalt, CoO, H_2O, is formed by adding solution of potash to solution of any salt of cobalt.

352. Sesquioxide of Cobalt, Co_2O_3, is procured when chlorine is passed through a mixture of the hydrated protoxide, and water.

$$3(CoO, H_2O) + Cl_2 = Co_2O_3, 3H_2O + CoCl^2.$$

Gentle heat expels the water. It is black, and insoluble in acids.

353. Sulphides of Cobalt. *Protosulphide* is obtained as hydrate by precipitating acetate of cobalt, by sulphuretted hydrogen; *Sesquisulphide* of cobalt is procured by decomposing sulphate, by sulphuretted hydrogen.

354. Chloride of Cobalt, $CoCl$, is got by passing chlorine gas over metallic cobalt. The hydrated chloride contains $6H_2O$; may be used in solution, as a *sympathetic ink*; letters written with this ink are invisible, until gently heated, when they appear of a brilliant blue (anhydrous chloride); on cooling the colour again disappears.

355. Nitrate of Cobalt, $Co\,2NO_3 . 6H_2O$, is obtained when nitric acid is added to the oxide. It is a brownish-red deliquescent salt; used as a reagent for the blow-pipe.

356. Sulphate of Cobalt, $CoSO_4 . 7H_2O$, is obtained by dissolving the protoxide, or carbonate in sulphuric acid.

357. Carbonates of Cobalt. Under different circumstances the following carbonates are obtained. Adding hot solution of carbonate of sodium to hot solution of salt of cobalt, $5CoO, 2CO_2 . 4H_2 O$; at ordinary temperature they give $4CoO, 2CO_2 . 7H_2 O$.

358. Ammonia Compounds of Cobalt. Many salts of cobalt form double salts with those of ammonium, as *Nitrate,* $CO\ 2NO^3, 6H_3N. 2H_2 O$; *Chloride,* $Co\ Cl^2, 6H_3 N, 3H_2 C$.

359. *Other Compounds of Cobalt.* **Cobalti-cyanide,** $MCy . Co\ Cy$; **Cobalt bloom, or Arsenate of Cobalt,** $Co_3\ 2AsO_4 , 4H_2 O$; **Iodide of Cobalt,** $Co\ I$; **Fluoride of Cobalt,** $Co\ F$; **Bromide of Cobalt,** $Co\ Br$; **Oxysulphide of Cobalt,** $CO_4\ SO$; **Tricobaltic Phosphide,** $Co_3\ P$.

360. Tests, &c.—

1. Black sulphide, with sulphide of ammonium.
2. Potash gives a deep blue pp. which on boiling becomes red.
3. Alkaline carbonates give a light red pp.
4. Ferrocyanide of potassium gives a dirty green pp.
5. Sulphuretted hydrogen, if acid, gives no pp.; a dark brown pp. if acetate of sodium is added.
6. Blue borax bead.

Nickel, and its Compounds.

361. Nickel (Ni.= 59 ; Sp. Gr. 8·82) was discovered by Cronstedt in 1751. It is found most abundantly as arsenide of nickel (*kupfernickel* or false copper); the metal is prepared from this ore, and *speiss* which is an arsenio sulphide deposited at the bottom of the pots, in the manufacture of *smalt.* From *speiss* the metal is obtained, by fusing with chalk and fluor-spar; reducing to powder; roasting to expel arsenic; dissolving in hydrochloric acid; diluting and adding chloride of lime, and milk of lime to precipitate iron, as sesquioxide, and arsenic; passing sulphuretted hydrogen through solution, precipitating copper, bismuth, and lead; boiling solution and precipitating cobalt, with chloride of lime; and finally, throwing down the nickel as hydrated oxide, by adding milk of lime; the nickel pp. is afterwards reduced by charcoal.

It is a white, hard, ductile, and malleable metal; it is not oxidised at common temperature of air; magnetic, but the property disappears above 630°; nitric acid dissolves it freely. It is used in the manufacture of *German Silver*, or *packfong*. The following proportions form a good alloy:—in 100 parts, 51 copper, 30.6 zinc, 18.4 nickel. *Tutenag* is a similar alloy. *Kupfernickel*, Ni As, is a natural arsenide of a reddish colour. *Arsenical nickel* is represented by $NiAs_2$. *Nickel glance*, (NiS As) is another native compound. Nickel is found in *meteoric stones*.

362. Protoxide of Nickel, NiO, is obtained when the Nitrate or Carbonate is ignited in a covered crucible. It is an olive green powder.

363. Peroxide of Nickel or Sesquioxide, Ni_2O_3. Got by heating the Carbonate or Nitrate nearly to redness, when it is a black powder. As a *hydrate* ($Ni_2O_3 . 3H_2O$) by treating the hydrated protoxide in solution with chlorine.

364. Chloride of Nickel, Ni Cl_2, is produced by dissolving the metal, or its oxide, in hydrochloric acid. It yields green crystals containing $9H_2O$. The anhydrous salt is yellow.

365. Sulphides of Nickel. *Protosulphide*, NiS, is a yellow native compound, and known as *Millerite* or *Capillary pyrites*. May be prepared by fusing sulphur and nickel. *Subsulphide*. Ni_2S. is got by reducing the sulphate by charcoal. *Bisulphide*, NiS_2, is procured on heating an intimate mixture of Carbonate of Nickel, Carbonate of Potassium, and Sulphur. It is a grey powder.

366. Sulphate of Nickel, $NiSO_4 . 7H_2O$, is prepared by adding sulphuric acid to the metal, or its oxide, or carbonate. It yields crystals of a green colour, which are very soluble in water. By adding caustic potash to the impure solution of speiss, a *Double Sulphate of Potassium and Nickel* is obtained, $Ni\ SO_4,\ K_2\ SO_4\ .\ 6H_2\ O$.

367. Carbonates of Nickel. Of these there are several having a green colour. The *Normal Carbonate* is obtained by adding the acid carbonate of sodium to a solution of the nitrate. *Emerald Nickel* is a native carbonate.

368. *Other Compounds of Nickel*:—**Antimonide of Nickel** $Ni_2\ Sb$; **Bromide,** $Ni\ Br$; **Iodide,** $Ni\ I$; **Fluoride,** $Ni\ F$; **Phosphide,** $Ni_3\ P$; **Phosphate,** $Ni\ P_2\ O^6$; **Cyanide,** $Ni\ Cy$; **Nitrite,** $Nni\ N_2\ O_4$; **Nitrate,** $Ni\ NO_3\ .\ 3H_2\ O$.

369. Tests, &c.—

1. Sulphuretted hydrogen, no pp.
2. Sulphide of ammonium, a black pp.
3. Ammonia, a pale green pp., soluble in excess.
4. Potash and soda, a pale green pp., *insoluble* in excess.
5. Carbonates of alkalies, apple-green pp., dissolved by carbonate of ammonium, giving a blue solution.
6. Ferrocyanide of potassium, a pale-green pp.
7. Ferricyanide of potassium, a yellowish-green pp.
8. A yellow borax bead.

The salts excite vomiting, and have a sweetish taste.

Iron, and its Compounds

370. Iron ($Fe = 56$; Sp. Gr. 7·84) is found very extensively diffused in nature, chiefly as oxides, carbonates, or sulphides. The following are the principal iron ores :—*Clay Ironstone* (an impure carbonate) ; *Black Band* (a carbonate) ; *Spathic* or *Protocarbonate* ($Fe\ CO_3$.) ; *Brown Hæmatite* (2 Fe_2

O_3, $3H_2O$.); *Red Hæmatite* (Fe_2O_3.); *Specular Iron Ore* (Fe_2O_3.); *Magnetic Iron Ore, or Loadstone* (FeO, Fe_2O_3); *Iron Pyrites* (FeS_2).

Manufacture. Clay ironstone, found in nodules, with coal and shale is the principal source of iron in Britain. The ore is first roasted to expel water, and carbonic acid; it is then subjected to intense heat in *blast furnace*, with coke and limestone in alternate layers; the iron is reduced as it descends, and as *carbide* is withdrawn at intervals through the tap hole; the slag which consists chiefly of silicates of lime, and alumina, collects at the bottom of the furnace, and is removed through a suitable opening. The oxygen of the blast, on entering the furnace, unites with carbon, forming carbonic anhydride, whilst the nitrogen escapes; each atom of the carbonic anhydride, in its course, combines with another atom of carbon, which yields carbonic oxide; this is mixed with free hydrogen, and carburetted hydrogen, and to a large extent escapes unburnt. The blast furnace is generally about 50ft. high, and 15ft. in the widest inside diameter; it is built of stone and brick, bound together with iron bands, and lined in the lower part with the most refractory firestone; about six tons of hot air per hour is supplied to the furnace by suitable blowing machines; with the *hot* blast three tons of coal will produce one ton of iron, whereas eight tons are required with the cold blast.

371. Cast Iron. The carbide of iron obtained from the ore by the above process, is run from the furnace into moulds of sand, and known as *pig iron*, or *cast iron*. Cast iron is distinguished as No. 1, *grey* iron, 2, *mottled*, and 3, *white* cast iron; small articles made of cast iron may be *decarbonized*, and thus rendered malleable, by heating them to redness for some hours in powdered hæmatite.

372. Wrought, or Malleable Iron is nearly free from carbon. The conversion of *cast* into *wrought iron* is effected by subjecting the former to the action of air, at a high temperature, burning off the carbon ; running the metal into the form of a cake, and cooling suddenly by pouring on it cold water ; breaking up the cake, and further purifying by *puddling*. In puddling, the metal is placed in a reverberatory furnace, and well stirred ; the mass becomes less fusible, and at length, quite granular; the heat is raised when the metal softens, is removed in balls or *blooms*, on the end of iron rods; is afterwards hammered or pressed in a *shingling press*, and subsequently rolled ; the bars are cut, again heated in reverberatory furnace, and finally rolled and cut for sale ; the best iron is repeatedly heated, and rolled to increase its toughness, by rendering the fibres more parallel. Pure iron is procured by mixing filings of the best bar-iron with $\frac{1}{5}$ the weight of pure peroxide of iron, and after covering with pounded glass, free from lead, exposing in a well-closed crucible, to the strongest heat of a forge.

373. The Bessemer Process. This is a mode of purifying iron by passing cold air through melted cast iron, and thus superseding the ordinary method of puddling and refining. In this process, the oxygen of the air combines with carbon of iron, forming carbonic oxide; in this reaction the temperature of the iron is greatly raised, and by the escape of carbonic oxide, the melted mass is very much agitated. During the operation 20 p. c. of iron is wasted, and a great portion of phosphorus and sulphur are retained; it is, however, a very successful method for Swedish charcoal pig-iron.

Properties.—Iron fuses with difficulty when perfectly pure; common iron melts at a white heat; is the hardest and toughest of the ductile metals; cannot be beaten out into thin leaves, but may be drawn into fine wire; may be *welded* at a red heat; is readily oxidised in damp air, but is not acted on by dry air; if very finely divided it has great affinity for oxygen.

374. Steel is iron in combination with less carbon than cast iron contains. *Natural steel* is prepared by heating the best cast iron, or native oxides, on the hearth of furnace with charcoal. *Blistered steel* is obtained by *cementation*. This process consists in heating to redness, bars of the purest iron with charcoal, mixed with common salt and wood-ash; the bars are generally about 3in. broad, and ¾in. thick; the operation occupies 6 to 10 days; steel thus obtained is called *blistered* steel; drawn into small bars and forged it is *tilted;* broken up and again welded into bars, it is *shear* steel; blistered steel fused, is *cast* steel. The last is more uniform in texture, and is used for best cutlery, punches, &c.; in *case-hardening*, iron is partially *cemented*.

Steel is harder, has a finer grain, and is more sonorous than iron; steel heated, and suddenly plunged in water becomes very hard; the hardness is modified by a moderate heat in an annealing furnace; lancets, razors, and penknives are *tempered* when the steel assumes a yellow colour, at about 430°; fine cutlery at straw colour, about 460°; table and carving knives, when brown, at 500°; and sword blades and saws, when there is a red or purple tinge, from 530° to 600°.

375. Protoxide of Iron or Ferrous Oxide, FeO, is obtained as white *hydrate*, by adding a solution of potash to one of pure protosalt of iron. The salts of this oxide are generally greenish-blue; their solutions when exposed to air rapidly oxidise, forming *ferric* salts.

376. Peroxide, Ferric Oxide, Red Oxide, or Sesquioxide, $Fe_2 O_3$. In the anhydrous form it is prepared by strongly heating the ferrous sulphate; it is then of a red colour, and is called *colcothar*, *crocus of Mars*, or *jeweller's rouge*, and is used for painting, and polishing glass; it occurs frequently in nature.

377. Hydrates of Sesquioxide of Iron. When an alkali is added to a solution of a salt of iron, a hydrate of sesquioxide is obtained, containing $3H_2O$. If dried at 212°, it contains only H_2O; above 500° all the water may be expelled; newly precipitated, this oxide dissolves freely in acids, forming ferric salts; the presence of gelatine, starch, &c. in solution, prevents its precipitation by alkalies; this oxide is used to remove sulphuretted hydrogen from coal gas; it is a *weak* base.

378. Black, or Magnetic Oxide, or Ferrosoferric Oxide, $Fe_3 O_4$. This is formed when iron is burnt in oxygen, or when steam is passed over red-hot iron. The *hydrate* is obtained by dissolving equal weights of ferrous sulphate in separate portions of water, boiling one with nitric acid to peroxidise it, then mixing with the other and pouring the mixture into a solution of *potash*. It forms a heavy crystalline powder.

379. Ferric Acid, $H_2 FeO_4$ is obtained when the sesquioxide is mixed with 4 parts nitre, and heated for an hour to full redness in a covered crucible; it yields the ferrate of potassium, a brown mass which gives a violet colour in a water solution; the acid is only known in combination with bases.

380. Ferrous Chloride, or Protochloride, $FeCl^2$, is got by passing dry hydrochloric acid gas over red hot iron wire. It has a grey colour, and is very soluble in water. The *hydrate* is procured by dissolving iron in hydrochloric acid; this contains $4H_2 O$.

381. Sesquichloride, or Perchloride of Iron, $Fe_2 Cl_6$, is prepared by introducing a red-hot iron wire into a bell jar of chlorine; the iron burns and forms crystalline, and very deliquescent scales of the perchloride. The *hydrate* is obtained by dissolving the hydrated peroxide, in hydrochloric acid. It forms large red crystals, $Fe_2 Cl^6$, $6H_2 O$.

382. Ferrous Iodide, or Protiodide, $Fe I_2$, is procured by digesting iron wire, or turnings, in a closed vessel with iodine, in water. The solution is green, which, evaporated out of contact of air, yields grey crystals, $Fe I$, $4H_2 O$. It is used medicinally, and to produce iodide of potassium.

383. There are Bromides of Iron corresponding to the chlorides.

384. Sulphides of Iron, *Protosulphide or Sulphuret of Iron,* FeS, is prepared by fusing iron filings with sulphur. It has a dark-bronze colour, and is used to obtain sulphuretted hydrogen. 60 parts fine iron filings, 2 sal ammoniac, and 1 flowers of sulphur mixed with water in a paste, forms a useful lute for joining iron vessels.

Bisulphide of Iron, FeS_2, is formed by mixing the protosulphide with half its weight of sulphur, subjecting the mixture to a heat somewhat below redness. *Magnetic Sulphide,* $Fe_7 S_8$, is frequently formed in heating sulphur and iron together. *Mispickel,* or *arsenio-sulphide of iron,* $FeS\,As$, is found in some of the Cornish mines.

385. Ferrous Nitrate, or Protonitrate of Iron, $Fe\,2NO_3 . 6H_2\,O$. is obtained when iron filings are digested by very dilute nitric acid. It is at first an olive brown, and afterwards a pale-green colour. It is *crystallized* by evaporation, *in vacuo,* over sulphuric acid. As is shown by the following equation, the above method does not yield a *pure* salt:—

$$10H\,NO_3 + 4Fe = 4(Fe\,2NO_3) + H_4\,N\,NO_3 + 3H_2\,O.$$

It is better prepared by using protosulphide of iron, with weak nitric acid.

386. Ferric Nitrate, or Pernitrate of Iron, $Fe\,3NO_3,\ x\,H_2O$. Nitric acid slightly diluted, and added to iron, yields this salt. A basic nitrate is formed at the same time.

387. Ferrous Sulphate, Protosulphate of Iron, commonly called *Sulphate of Iron, Copperas,* or *Green Vitriol,* $Fe\,SO_4 . 7H_2O$; Sp. Gr., 1.85. This salt is procured on a large scale from *iron pyrites,* by heating that ore, and afterwards exposing it to moist air. It has then a grass-green colour, and contains ferric sulphate, It is obtained in a purer form, by heating together 1½ protosulphide of iron, 1½ sulphuric acid, and 4 water. This mode yields bluish-green crystals. When exposed to air, the salt assumes a reddish colour, by absorbing oxygen, and forming ferric sulphate, $2Fe_2O_3,\ SO_3 . 3H_2O$. If heated, it loses 6 atoms of water, forming a white powder; when heated above 535°, it becomes anhydrous. If heated to redness, it is decomposed, yielding sulphuric anhydride, which is partially resolved into *sulphurous* anhydride.

$$2Fe\,SO_4 = Fe_2\,O_3 + SO_2 + SO^3.$$

The remaining sesquioxide is known in commerce as *colcothar*. The salt is used by dyers and calico printers; used too in the preparation of *Prussian blue*, ink, fuming sulphuric acid, or Nordhausen acid, and as a medicine. It forms double salts with potassium and ammonium, as $Fe\,SO_4$, $K_2\,SO_4\,.\,6H_2O$.

388. Ferric Sulphate, Persulphate, or Sesquisulphate of Iron, $Fe_2\,3SO_4$, is made by adding one equivalent oil of vitriol to two equivalents ferrous sulphate; the mixture is boiled, and nitric acid is gradually dropped in, as long as red fumes come off. It has a buff colour; is found native as a white powder in Chili. It forms a double salt with ammonium, $H_4NFe2SO_4$, $12H_2\,O$.

389. Subphosphide of Iron. Fe_2P, is obtained by the ignition of phosphate of iron with charcoal. It is brittle; has a grey colour; phosphorus renders iron more fusible; injurious to iron when more than one per cent. in it.

390. Phosphates of Iron. *Ferrous Phosphate*, $Fe\,H\,PO_4$ is procured by adding a solution of common phosphate of sodium to a ferrous salt. It is at first white, but by exposure to air becomes blue. *Vivianite* is a native phosphate $Fe''\,HPO_4$, $2Fe''\,PO_4$. *Ferric Phosphate* $Fe''\,PO_4$, $2H_2O$. is a white insoluble body, precipitated from perchloride of iron, by adding an alkaline orthophosphate.

391. Ferrous Carbonate, or Protocarbonate of Iron, $Fe\,CO_3$. This salt may be made by adding the carbonate of an alkali to a solution of a ferrous salt; if oxygen is excluded, it is a greenish powder; if air or oxygen is not excluded, it is rapidly converted into the red hydrated sesquioxide. The mineral called *clay-iron ore*, is found abundantly in England, being the chief source of the metal. The waters of Tunbridge Wells, known as *chalybeate waters*, contain 2 to 3 grains per gallon of the carbonate of iron.

392. Oxalates of Iron. *Ferrous Oxalate*, $2FeC_2O_4, 3H_2O$, is got by adding oxalate of ammonium to ferrous sulphate, in solution. It forms a yellow crystalline powder. *Ferric Oxalate* is procured by adding a soluble oxalate to a ferric salt. It is a yellow powder. It forms double salts which are freely soluble; on this account acid oxalate of potassium removes ink stains from linen.

393. Tests, &c.—*Ferrous Salts.* They have a green colour, inky taste, and redden litmus slightly.

1. If acid, sulphuretted gives no pp.
2. Sulphide of ammonium gives a pp. of greenish black hydrated sulphide.
3. The alkalies give pp. of hydrated protoxide—oxygen is rapidly absorbed from air, changing it into sesquioxide.
4. Ferrocyanide of potassium gives a pale blue pp., which rapidly becomes a *deep* blue.
5. Ferricyanide of potassium gives a rich blue pp., a Prussian blue.
6. A green glass with borax, in *reducing* flame.

Ferric Salts. The solutions are generally brownish-yellow.

1. Sulphuretted hydrogen gives a milky-white pp. of sulphur, and reduces them to ferrous salts.
2. Sulphide of ammonium gives a black pp. of sulphide of iron.
3. The alkalies and their carbonates throw down reddish brown hydrated peroxide.
4. Sulphocyanide of potassium gives a blood-red solution.
5. Ferrocyanide of potassium, blue pp.—common Prussian blue.

6. Ferricyanide of potassium gives no pp., but a greenish colour.
7. Tincture of galls. gives an immediate blue black pp.
8. In reducing flame, a green glass with borax—the colour disappears in oxidising flame.

Chromium, and its Compounds.

394. Chromium (Cr = 52.5; Sp. Gr. 6.81) occurs in nature as *Chromate of lead*, Pb CrO_4, and as *protoxide of iron* with *sesquioxide of chromium*, FeO, Cr_2 O_3. The metal is obtained from the oxide, by mixing it, finely powdered, with one-tenth its weight of charcoal, making a paste with oil, and then strongly heating in a crucible. The reduction is difficult. By this method, it contains carbon with the metal; it scratches glass; takes a good polish; has the colour of platinum; has no application in the arts.

395. Oxides of Chromium. *Protoxide*, CrO, is obtained as a brown *hydrate*, by adding caustic potash to chromous chloride; it readily absorbs oxygen from air. *Sesquioxide*, Cr_2 O_3, is prepared by exposing the chromate of mercury, or chromate of ammonium to a dull red heat. It is green, not changed by heat; used in enamel and porcelain painting; may be obtained as *hydrate*, by acidulating bichromate of potassium, with sulphuric acid, and boiling with the addition of alcohol. It forms the colouring matter of the *emerald*. *Chrome iron-stone* FeO, Cr_2 O^3, is the chief mineral of chromium; it is scarcely attacked by acids; does not fuse in the furnace. *Perchromic Acid*, H CrO^4, appears to exist; no compounds of it are known.

396. Chromic Anhydride, or Chromic Acid, CrO_3, is most easily obtained by mixing 4 measures of a saturated solution of bichromate of potassium with 5 sulphuric acid; chromic anhydride separates in crimson needles; they have a sour and metallic taste; it acts powerfully as an oxidising and bleaching agent.

397. Anhydro-chromate of Potassium, *Red Chromate,* or *Bichromate of Potash,* $K_2 O, 2CrO_3$, is prepared by heating *chrome ironstone* to redness, and cooling in water; reducing it to powder; heating in reverberatory furnace with chalk and carbonate of potassium; digesting in water with addition of carbonate of potassium, then supersaturating with nitric acid; and finally evaporating the solution. It forms red crystals which are anhydrous; at a red heat they fuse into a liquid, and afterwards congeal, and at last fall into a powder. *Neutral Chromate,* or *Yellow Chromate of Potash,* $K_2 CrO_4$, is obtained by adding carbonate of potassium to a solution of anhydro-chromate. It forms yellow prismatic crystals having a disagreeable taste; has a crimson colour if heated to 400°, but resumes the yellow on cooling. A *Terchromate,* $K_2 O, 3CrO_3$, has been obtained as red crystals.

398. Other Chromates. *Chromate of Sodium,* $Na_2 CrO_4 . 10H_2O$, is prepared similarly to chromate of potassium: there is also an *acid chromate* of sodium. Chromote of barium, $Ba CrO^4$, is a yellow powder. *Chromate of Lead,* $Pb CrO^4$, is procured when the chromate of potassium is added to a solution of acetate of lead. It forms the paint called *chrome yellow.* By digesting the neutral chromate of lead, in a weak solution of potash, the *dibasic chromate* is obtained $2PbO, CrO^3$. These chromates are used as oil and water colours, and in calico-printing, and dyeing. *Vanquelinite* is a double chromate of lead and copper $\left.\begin{matrix}Pb\\Cu_{\frac{1}{3}}\end{matrix}\right\} 2O . 4 \left(\begin{matrix}Pb_{\frac{2}{3}}\\Cu_{\frac{1}{3}}\end{matrix}\right) CrO_3$. *Melanochroïte,* $3Pb_2 O . 2Cr_2 O_3$, is a dark red mineral. *Basic Mercurous Chromate,* $3H_2 CrO_4, Hg_2 O$, is obtained when basic mercurous nitrate is added to a chromate. *Chromate of Silver,* $Ag_2 CrO_4$, has a dark red colour. *Bichromate of Chloride of Potassium,* KCl, CrO^3, forms orange-coloured crystals.

Sesquisulphide of Chromium, $Cr_2 S_3$, is obtained as black scales like black lead, when the vapour of bisulphide of carbon is passed through a red-hot tube, containing sesquioxide of chromium.

399. Compounds of Chromium and Chlorine. *Chromous Chloride,* $Cr Cl^2$. This is a white substance, which gives a blue solution; it is prepared by heating the chronic chloride to redness in a current of dry hydrogen. *Chromic Chloride,* or *Sesquichloride.* $Cr_2 Cl^6$, is procured as violet-coloured scales, when dry chlorine is passed over a mixture of fine sesquioxide of chromium, and charcoal. *Chlorochromic Acid,* $Cr Cl_2 O_2$, is a red fuming liquid; water decomposes it; it is prepared by heating a mixture of chloride of sodium, chromate of potassium, and sulphuric acid.

400. Fluoride of Chromium, $Cr F_6$ is got by distilling 4 parts chromate of lead, 3 powdered fluorspar, and 8 oil of vitriol in platinum retort. It forms deep-red fumes, which may be condensed into a red liquid, or crystals.

401. Nitride of Chromium, $Cr_3 N_4$?, is obtained by heating in a current of dry ammonia, the anhydrous chloride of chromium. It is not soluble ; has a chocolate-brown colour.

402. Sulphates of Chromium, $Cr_2 3SO_4$. Of this salt there are *three* kinds. The *green* variety, $Cr3SO_4$. $5H_2O$, procured by boiling hydrated oxide of chromium, with oil of vitriol ; this does not crystallize. The *violet* form, obtained by adding 9 parts of oil vitriol to 8 dried hydrated oxide of chromium, in a vessel exposed to air. This yields crystals which may be afterwards dissolved in water, and separated by alcohol ; they contain $15H_2O$. This kind forms with sulphate of potassium or ammonium, the double salt, *chrome alum*, $K Cr 2SO_4$, $12H_2O$. Either of the above sulphates, heatedto 700° becomes anhydrous, and forms the *red* kind, which is insoluble in water, $Cr_2 3SO_4$

403. Nitrate of Chromium, $Cr 3NO_3$ is obtained when nitric acid is added to the hydrated sesquioxide ; it has a green colour.

404. Oxalates of Chromium. By mixing a solution of the green sesquichloride with oxalate of ammonium, a green *insoluble* pp. is obtained. When the hydrated sesquioxide is used with oxalic acid, a green *soluble* oxalate is procured. Oxalate of chromium, with alkaline and earthy oxalates, yields two series of double salts : *Dark blue Salts*, $M'_3 Cr'' 3C_2O_4$; *Red Salts*, $M'Cr'' 2C_2O_4$.

405. Tests, &c. *Chromous Salts:—*

1. Potash gives a brown pp. of hydrated protoxide.
2. Ammonia gives a greenish-white pp.
3. Sulphide of potassium gives black sulphide.
4. Ferrocyanide of potassium greenish-yellow pp.
5. These salts reduce solutions of gold to metal.

Chromic Salts:—

1. Potash and soda give green pp.; excess dissolves it; boiling reprecipitates it.
2. Ammonia gives gelatinous pp.
3. Carbonates of alkalies give green pp.

Chromates:—

1. Yellow pp. with salts of lead.
2. Orange pp. with salts of mercury.

3. Red pp. with salts of silver.
4. Decomposed, when boiled with dilute oil of vitriol, and sugar, or alcohol.
5. Give *green* colour to borax in reducing flame, and *red* in oxidising flame.

Manganese, and its Compounds.

406. Manganese (Mn = 55; Sp. Gr., 8.013) is found in nature most commonly as peroxide, or black oxide of manganese, MnO, MnO_3. The metal is procured by mixing the carbonate into a paste with oil; putting the mixture in a crucible lined with charcoal, and gradually heating to redness; then submitting for 2 hours to a white heat. It is thus obtained as a metallic globule, having a grey colour. It tarnishes in air; gives off an unpleasant smell when handled; is very feebly magnetic; it renders iron harder and more elastic.

407. **Protoxide of Manganese, or Manganous Oxide**, MnO, is made by strongly heating the carbonate in a current of hydrogen. It has a dirty green colour; burns like tinder above 600°; with an alkali, it forms the following *hydrate*, MnO, H_2O.

408. **Sesquioxide of Manganese, or Manganic Oxide**, Mn_2O_3. This is produced when the carbonate is heated for some time to redness in an open vessel. It is a dark-brown powder. As a *hydrate*, it is obtained by passing chlorine through manganous carbonate, in water. This oxide gives a violet, or pink tinge to glass. The andydrous oxide is found native and known as *brauite*. *Manganite* is the hydrated sesquioxide, Mn_2O^3, H^2O.

409. Binoxide, Peroxide, Deutoxide, or Oxide of Manganese, MnO, MnO_3; Sp. Gr. 4.94. This is found native. It occurs in Devonshire, Aberdeenshire, &c. When ure, it is called *pyrolusite;* when amorphous, it is *psilomelane; Varvicite* is a crystalline hydrate, Mn_2O_3, $2MnO_2$, H_2O. *Wad* lso is a hydrate. It is a good conductor of electricity; with cids it is a useful oxidising agent; does not unite with acids, but when they reduce it to protoxide it combines with them. It is used to supply oxygen; in preparation of chlorine; by glass maker and calico printer.

410. **Red Oxide of Manganese,** Mn_3O_4 **is formed when any of the oxides of manganese are heated to redness in the air.** ***Hausmannite*** **is a red oxide.**

411. **Manganic Acid,** H_2MnO_4. This is obtained by fusing equal parts of caustic potash, and finely powdered peroxide of manganese. This, with a little water, is green, more dilute, it is purple, and still more red. It is hence called *mineral chameleon.* Nitric acid added, changes the green into the red kind.

412. **Manganates.** These salts are green, but are readily changed to red by the addition of a little free acid; this arises from the formation of a permanganate:—

$$5K_2MnO_4 + 4H_2SO_4 = 4KMnO_4 + MnSO_4 + 3K_2SO_4 + 4H_2O.$$

Sulphurous, phosphorous, and nitrous acids reduce them, rendering them colourless:—

$$K_2MnO_4 + 2H_2SO_3 = MnSO_4 + K_2SO_4 + 2H_2O.$$

413. **Permanganic Acid,** $HMnO_4$, is easily obtained by boiling the green solution of manganate of potassium. Organic matter decomposes it, it must therefore be filtered through asbestos. It forms ruby-coloured crystals. *Permanganate of potassium* is used to determine the amount of organic matter in air; *Condey's Disinfecting Liquid* consists of the manganate and permanganate of potassium; a solution of permanganate is sold by the name of *ozonized water.* Permanganic acid forms permanganates with lead, silver, barium, and ammonium.

414. **Protosulphide of Manganese,** MnS, xH_2O, may be obtained by adding the sulphide of ammonium to a manganous salt; thus prepared, it is a yellowish red hydrate. There is a native sulphide found in Cornwall, known as *manganese blende.*

415. **Chlorides of Manganese.** *Manganous Chloride* or *protochloride,* $MnCl_2, 4H_2O$. This is a waste product in the ordinary method of preparing chlorine. This residue is made to yield the pure chloride, by

passing sulphuretted hydrogen through its solution, and afterwards adding newly precipitated sulphide of manganese. The salt is formed as pink crystals. *Manganic chloride*, $Mn_2\ Cl_6$, is formed when cold hydrochloric acid is added to the sesquioxide; has a dark brown colour; must be concentrated *in vacuo;* a gentle heat converts it into $2Mn\ Cl_2$, giving off 2 eqs. of chlorine. An *Oxychloride*. or *Perchloride*, $Mn_2\ Cl_7$, is produced by adding *fused* chloride of sodium to a solution of permanganate of potassium, in sulphuric acid. It is a green vapour, which may be condensed at 0° into a greenish-brown liquid.

416. There are *Fluorides* corresponding with the above *chlorides.*

417. **Nitrate of Manganese,** $Mn\ NO_3 . 3H^2O$, is procured by adding dilute nitric acid to the protoxide, or carbonate. By evaporation, *in vacuo*, it forms prismatic crystals, having a bitter taste.

418. **Sulphate of Manganese,** $Mn\ SO_4 . 5H_2O$. This is obtained on a large scale by mixing the black oxide with sulphuric acid into a paste, then heating to dull redness; oxygen is evolved, and on washing the dried mass, the salt may be obtained in solution, and afterwards in crystals by evaporation. It is used in dyeing and calico printing; when cloth is passed through a solution, and then through an alkali, protoxide of manganese is left on it, forming the *manganese brown* colour. The crystals are slightly pink, and have a bitter taste. It forms double salts with potassium and ammonium—$Mn\ SO_4$, $K_2\ SO_4$, $6H_2O$. There is also a sesquisulphate of manganese.

419. **Carbonate ot Manganese,** $Mn\ CO_3$. This is precipitated as *hydrate* when an alkaline carbonate is added to the protochloride, $2Mn\ CO_3 . H_2\ O$. The native carbonate is called *Manganese spar, Dialogite. Red Manganese, Brown spar, or Manganspath.*

420. **Tests:—**

1. Sulphuretted hydrogen produces no pp.
2. Sulphide of ammonium gives flesh-coloured sulphide.
3. Potash and soda give white hydrated protoxide.
4. Ammonia gives similar pp., soluble in excess.

5. Carbonates and bicarbonates throw down a white carbonate.
6. Ferrocyanide of potassium gives a *white*, and ferricyanide a *brownish-red* pp.
7. A *trace* of manganese may be detected by boiling the solution with weak nitric acid, and a little peroxide of lead, the red permanganic acid being produced, if free from chlorides.
8. Fused with carbonate of sodium, a bluish-green manganate of sodium is formed.

Uranium, and its Compounds.

421. Uranium, U = 120, was discovered by Klaproth, in 1789, in the mineral *pitchblende*, $2UO, U_2O_3$. *Uranite* is a double phosphate of calcium and uranium, $Ca\ 2(U_2\ O_2)\ 2PO_4, 8H_2O$. *Chalcolite* has this formula $Cu\ 2(U_2O_2)\ 2PO_4, 8H_2O$. The metal is obtained from the chloride, by decomposition, using sodium, as in the preparation of magnesium. It is white, and somewhat malleable; burns brilliantly when heated in air.

422. Compounds of Uranium:—

Protoxide, or Uranous Oxide	UO.
Black Oxide	$2UO, U_2O_3$
Green Oxide	$UO, U_2\ O_3$
Sesquioxide, or Uranic Oxide	$U_2\ O_3$
Chloride of Uranium	$U_2\ Cl_3$
Bichloride, or Uranous Chloride	$U\ Cl_2$
Oxychloride of Uranium	$UO\ Cl$
Sulphate of "	$U\ SO_4$
Nitrate of "	$U_2O_2\ 2NO_3 . 6H_2O$

423. Tests, &c.

1. Sulphide of Ammonium gives a dark-brown pp.
2. Sulphuretted hydrogen, no pp.
3. Potash, or Ammonia throws down an orange-yellow *uranate*,
4. Ferrocyanide of Potassium gives a brown pp.
5. Alkaline carbonates give a yellowish green pp.
6. Borax bead, green, in the *inner*, and yellow in the *outer* flame.

Tin, and its Compounds.

424, Tin, Sn=118; Sp. Gr. 7.292. The chief ore of this metal is *tin-stone*, or binoxide. It occurs abundantly in Cornwall. With sulphur it is met with as *tin-pyrites*. If *tin-stone* is found with other ores in veins, it is called *mine-tin*, and if as an alluvial deposit, *stream tin*. The metal is obtained by *stamping* and washing the ore; roasting in a reverberatory furnace to expel arsenic and sulphur, when it becomes a yellowish-brown powder; exposing the mass to the air for a few days; it is then washed to remove sulphate of copper, and oxide of iron; exposed to reverberatory furnace with $\frac{1}{8}$ its weight of small coal; cast in ingots; remelted on inclined hearth of furnace *(liquation)* separating the purer kind which is most fusible; the less fusible metal, when remelted, forms *block tin*. The more pure metal, whilst still in a fused state in a pan, is stirred a few hours with wet stakes of wood, causing impurities to rise to the surface. If this is again melted, and dropped from a height, it yields *grain*, or *dropped* tin.

Tin has a white colour with a slight tinge of yellow; is softer than gold; is malleable, though wanting in tenacity; beaten into thin leaves, it forms tin-foil; tin-foil of commerce usually contains 30 to 40 per cent. of lead; tin crackles when bent; gives off a peculiar smell when rubbed; fuses at 442°; strong hydrochloric acid, when heated, dissolves tin; dilute nitric acid acts powerfully on it, forming hydrated binoxide, or *metastannic acid*; strong oil of vitriol, boiled on it, forms the sulphate of peroxide; is slowly acted on by air, or moisture; *powdered tin* is made, by shaking the melted metal, in a wooden box, chalked inside.

425. Tin Plate is an alloy of tin and iron. It is procured by dipping carefully cleansed iron plates, in melted tin. The crystalline appearance, known as *moirée metallique*, is produced by heating tin plate, and quickly sponging it with an acid, composed of 2 parts nitric, and 3 hydrochloric acid, with 8 water. Pins are *tinned*, by boiling them a few minutes, in a solution consisting of 1 part cream of tartar, 2 alum, 2 common salt, and 12 water, with granulated tin.

426. Tin Alloys. *Britannia metal* consists of tin, copper, antimony, bismuth and a little lead *Pewter* contains about 4 parts tin, to 1 lead. *Queen's Metal* is composed of the same metals as Britannia metal, in different proportions. *Solder* is an alloy of tin and lead.

427. Oxides of Tin. *Stannous Oxide* or *Protoxide* of Tin. SnO. This is procured as a white hydrate, $2SnO, H_2O$, when a solution of stannous chloride is added to carbonate of sodium in excess. It is of a dark colour. When anhydrous it is a dark grey, or black powder. *Binoxide of Tin*, SnO_2 occurs native as *tin stone*. This is the only ore that is worked; when crystallized, it is generally brown. The hydrate is an acid, and may be procured in two conditions, *Stannic* and *Metastannic*.

428. The Stannic acid, $H_2 SnO_3$, may be obtained by precipitating the tetrachloride of tin, by ammonia. The Metastannic $H_2 Sn_5 O_{11}.4H_2 O$ by treating metallic tin with nitric acid, both these acids unite with metals, forming *Stannates*, and *Metastannates*. *Stannate* of *Potassium* $K_2 SnO_3$, $4H_2 O$ is prepared by heating peroxide of tin with caustic potash. It is used as a mordant. *Sesquioxide of Tin*, $Sn_2 O_3$. This is obtained by boiling hydrated sesquioxide of iron, with a solution of stannous chloride. It gives a purple pp. with salts of gold.

429. Sulphides of Tin. *Protosulphide*, SnS, is formed by heating sulphur with tin. It is brittle, and has a brownish-black colour. *Sesquisulphide*. $Sn_2 S_3$ is obtained when the protosulphide is heated with one-third its weight of sulphur. It has a metallic lustre, and yellowish-grey colour. *Bisulphide of Tin*, $Sn S_2$. This is known as *Mosaic gold*. It is got by amalgamating 12 parts tin with 6 mercury; reducing this to powder, and mixing with 7 parts sublimed sulphur, and 6 sal ammoniac; the mixture is gently heated in a flask, driving off white fumes, and then heated to redness. It forms soft golden flakes; aqua regia is the only acid that dissolves it; it is imported from Holland and Germany as *bronze powder* for ornamental work.

☞ **430. Chlorides of Tin.** *Stannous Chloride*, $Sn Cl_2$. Got as hydrate by dissolving tin in hydrochloric acid. It forms prismatic needles, $Sn Cl_2, 2H_2O$; the water may be removed by heating to 212° F; the anhydrous chloride may be obtained too, by distilling equal weights of granulated tin and corrosive sublimate,

$$Hg Cl_2 + Sn = Sn Cl_2 + Hg.$$

It forms a grey solid, known as *butter of tin*. This chloride is used as a *mordant*, and generally called *salts of tin*. It acts powerfully as a reducing agent; it forms double chlorides, with many other chlorides; with solution of gold it yields *Purple of cassius*; it decomposes the salts of mercury, silver, and gold. *Stannic Chloride, Tetrachloride, or Bichloride of Tin*, $Sn Cl_4$. When one part tin filings is distilled with 4 of corrosive sublimate, this chloride passes over. It is a colourless liquid, giving off fumes in air. With water, it forms a hydrate, $Sn Cl_4 \cdot 5H_2O$. An excess of water precipitates hydrated stannic acid. Metallic zinc decomposes this chloride; it is much used by dyers; forms double salts with soluble chlorides.

431. Tests, &c.—*Stannous Salts* :—

1. Sulphuretted hydrogen and sulphide of ammonium give a deep brown protosulphide.
2. Potash and soda give a white pp. of hydrated protoxide, soluble in excess.
3. Ammonia, alkaline carbonates, and bicarbonates give a white pp., *insoluble* in excess.
4. Corrosive sublimate gives a white pp.
5. Granulated zinc, in acidified liquid, separates tin in crystals.
6. With chloride of gold, purple of cassius is formed.
7. Ferrocyanide of potassium gives a white pp.

Stannic Salts :—

1. Sulphuretted hydrogen, and sulphide of ammonium, give a dirty yellow pp. of bisulphide of tin.
2. Potash and soda, a white pp., *soluble* in excess.
3. Ammonia and alkaline carbonates, a white pp., *insoluble* in excess.
4. Corrosive sublimate, and chloride of gold give *no* pp.

All the compounds of tin yield, with carbonate of sodium in reducing flame, metallic tin.

Arsenicum, and its Compounds.

432. Arsenicum or Arsenic, (As = 75 ; Sp. Gr. of solid 5.7 to 5.9. Atom. Vol. ½). This metal is generally found native in combination with iron, cobalt, nickel, copper, or tin. *Mispickel*, FeAsS, an arsenical sulphide of iron, or *arsenical pyrites* is the chief source of arsenic. *Realgar*, the red bisulphide, and *orpiment*, the yellow tersulphide, are rarer ores of arsenic.

The metal is obtained by roasting the *ore*, and collecting the arsenious anhydride, which is sublimed in chambers; then mixing with a little charcoal, and heating in a crucible, which is covered by another crucible, luted; the sublimed arsenic is condensed in the upper crucible.

The metal has a bright steel-grey colour ; is very brittle; volatilizes without fusing at about 400°; slowly oxidises in moist air, forming *fly-powder*; at common temperatures, has no taste or smell, but has smell of garlic when volatilized; forms chloride of arsenic when dropped into chlorine ; nitric acid and aqua regia dissolve it, forming arsenic acid ; hydrochloric acid does not dissolve it; heated in air, it forms arsenious anhydride. It is used in the preparation of green and yellow pigments ; in manufacture of flint glass, and as a poison for vermin.

433. Arsenious Acid. or Arsenious Anhydride, As_2O_3. This in commerce is know as *white arsenic*, and is obtained as described in the last par. ; it exists in two forms, the *vitreous* and *crystalline* ; is nearly tasteless ; both kinds dissolve freely in hydrochloric acid ; water at 212° dissolves 11 to 12 per cent. ; when fused with dry acetate of potassium, *cacodyle* is given off ; arsenious acid acts as a deoxidizer.

434. Arsenites. Arsenious acid forms with the alkalies, soluble arsenites ; *Fowler's mineral solution*, or *tasteless ague-drop* is the arsenite of potassium; arsenite of copper, or *Scheele's green*, ($Cu\ H\ As\ O_3$), and *Schweinfurt green* ($3Cu\ As_2\ O_4$, $Cu\ 2C_2\ H_3\ O_2$), or *emerald green* are used extensively as pigments.

435. Arsenic Anhydride or Arsenic Acid, $As_2\ O_5$. This acid is obtained as a white mass by distilling a mixture of 1 part hydrochloric acid, 12 nitric acid, and 4 arsenious acid. It is a deliquescent anhydride; it dissolves in 6 parts cold, and 2 boiling water; sulphurous acid reduces it to arsenious acid; with aniline it gives a purple dye; it has been used of late by calico printers in place of tartaric and phosphoric acids.

436. Arsenates. These are tribasic like the phosphates, and may be represented generally by $M_3\ As\ O_4$. One of the most important compounds is arsenate of sodium, $Na_3\ As\ O_4$, $12H_2\ O$, which is prepared by saturating arsenious anhydride with soda-ash, and igniting the dried mass, in a reverberatory furnace. It is used by calico printers. Paper, impregnated with the solution and dried, is used as fly-poison, *Papier Moure.*

437. Sulphides of Arsenic, *Realgar*, or *Bisulphide* of *Arsenic* $As_2\ S_2$. This occurs native as red crystals. It is prepared by heating 9 parts arsenicum, and 4 sulphur. *White Indian Fire* contains 24 parts saltpetre, 7 sulphur, and 2 realgar. *Orpiment*, *Tersulphide of Arsenic*, or *Sulpharsenious Anhydride*, $As_2\ S_3$, It is a native compound.; may be obtained by passing sulphuretted hydrogen through a solution of arsenious acid in hydrochloric acid; it forms a yellow powder. It is the basis of *King's yellow.*

438. Sulpharsenic Anhydride. *Persulphide* or *Pentasulphide of Arsenic* $As_2\ S$ This is readily got when sulphuretted hydrogen is passed through a strong solution of arsenic acid. It has a yellow colour. It is insoluble in boiling water.

439, Terhydride of Arsenic, or Arsenuretted Hydrogen, $As\ H_3$. This is a gas, and is prepared best by heating equal weights of powdered arsenicum, and zinc, and then adding hydrochloric acid to the alloy. It has the smell of garlic; it is remarkably poisonous; three chemists have died in experimenting with it; blackens paper dipped in solution of nitrate of silver, but does not change colour, if paper is impregnated with lead salt it is inflammable, burning with bluish white flame; may be liquified under atmospheric pressure at—40°.

440. Terchloride of Arsenic $As\ Cl_3$. This is the only known chloride of arsenic. It is obtained when powdered arsenic is dropped into a jar of chlorine. It is a densé, transparent and oily-looking liquid; does not freeze at—20° ; fumes in air; a powerful poison; a solution is used as a medicine.

441. Teriodide of Arsenic, $As\ I_3$, is got by heating iodine and arsenicum in a flask. It appears in flakes of a red colour. Terbromide $As\ Br_3$, is obtained in a similar manner. It is a crystaline substance. Terfluoride $As\ F_3$, is procured by distilling fluorspar, arsenious anhydride, and oil of vitriol. It is a colourless liquid, which corrodes glass.

442. Tests, &c:—

1. Sulphuretted hydrogen gives a yellow pp. in solution, acidified with hydrochloric acid. Ammonia dissolves this pp., but does not dissolve yellow sulphide of cadmium, and thus they may be distinguished.
2. Ammonio-nitrate of silver gives a yellow pp. of arsenite of silver.
3. Ammonia-sulphate of copper gives, with arsenious acid, a green pp.
4. By reduction with carbonate of sodium and charcoal, giving a steel-grey ring in the tube used.
5. By *Marsh's test*, in which arsenic forms arsenuretted hydrogen, and may be burnt, giving distinctive spots on a cold plate; or may be decomposed by passing through a heated tube, producing a steel-grey ring.
6. By *Reinsch's test*, in which metallic arsenic is obtained as a film on copper, may be driven off by heat, and collected in a closed tube.

Antimony, and its Compounds.

443. **Antimony,** $Sb=122$; Sp. Gr., 6.71. This metal is sometimes found native, but is always prepared from the natural *sulphide.* In its preparation the ore is melted, by which, many of the insoluble earthy impurities are removed; it is cast in cakes, and afterwards powdered ; it is then heated to drive off sulphur ; it is next mixed with one-sixth its weight of powdered charcoal, and made into a paste with solution of carbonate of sodium ; the mixture is now heated in crucibles, when the metal collects at the bottom, and scoria, or *crocus* of *antimony*, in the upper part ; by remelting, the metal is prepared for market.

This is a bluish-white metal ; it is very brittle ; powdered antimony burns in chlorine; it is not dissolved by hydrochloric acid, but freely in aqua regia; it is oxidised by nitric acid, and boiling sulphuric acid; it fuses at 840°. *Type metal* contains 4 parts lead and 1 antimony; *music type* contains tin. *Réaumur's alloy* consists of 7 parts antimony, and 3 iron filings.

444. **Oxides of Antimony.** *Antimonic Oxide, Sesquioxide,* or *Teroxide* of *Antimony,* Sb_2O_3. This is prepared by boiling to dryness powdered antimony, with excess of sulphuric acid; sulphuric acid is removed by washing with water and carbonate of sodium. It is a white powder; it burns like tinder in air; is found native as *white ore of antimony.*

445. **Antimonic Anhydride,** or *Peroxide of Antimony,* Sb_2O_5. This oxide is formed by treating the metal with nitric acid. It has a pale yellow colour ; is tasteless, and insoluble in water.

446. Antimoniates. Antimonic acid forms neutral and acid salts. The following are some of these compounds :—*Acid-antimoniate* of *potassium*, $K_2 Sb_4 O_{11}$; *Acid-metantimoniate* of *potassium*, $K_2 H_2 Sb_2 O_7, 6H_2 O$; *Acid-metantimoniate* of *sodium*, $Na_2 H_2 Sb_2 O_7 . 6H_2 O$.

447. Antimonuretted Hydrogen, $Sb H_3$? This is got by adding sulphuric or hydrochloric acid to an alloy of zinc and antimony. It is a gas, having no colour, and nearly free from odour; burns with a greenish-white flame, yielding white fumes of oxide of antimony; is burnt in testing for antimony, *Marsh's test* (442).

448. Sesquisulphide, Crude Antimony, or Tersulphide of Antimony, $Sb_2 S_3$. May be got by fusing antimony and sulphur. It is dark grey, and has a metallic appearance. The oxide with the sulphide forms compounds known as *saffron* of *antimony*, and *liver* of *antimony*. The orange-coloured hydrated sulphide is precipitated from salts of antimony by sulphuretted hydrogen. *Kermes mineral* is formed by fusing this sulphide with carbonate of sodium; *Red antimony ore* $Sb_2O_3,2Sb_2S_3$, is a native oxysulphide. *Antimony vermillion*, used as a red paint, is the artificial sulphide. *Glass of antimony* is an oxysulphide. *Golden sulphide of antimony* is obtained from the mother liquor used in preparing Kermes mineral. The native sulphide, *grey antimony ore*, is generally found of a bluish-black colour, crystallized in four-sided prisms, with granite or slate rock.

449. Persulphide of Antimony, or Pentasulphide of Antimony, $Sb_2 S_5$. This is obtained by passing sulphuretted hydrogen through a solution of pentachloride of antimony. It is an orange-coloured powder. With potash and soda, it forms *sulphantimoniates*, as sulphantimodiate of sodium, $Na_3 SbS_4 . 9H_2 O$.

450. Chlorides of Antimony. *Terchloride of Antimony*, $Sb Cl_3$. This is produced when powdered antimony is sprinkled into a jar of chlorine, or by distilling 8 parts powdered antimony with 3 corrosive sublimate.

$$2Sb + 2Hg\ Cl_2 = SbCl_3 + SbHg + Hg\ Cl.$$

This is a soft substance, hence called *butter* of *antimony*; it deliquesces in air. It is used to bronze gun barrels. *Powder* of *Algaroth* an *oxychloride* may be represented by $2Sb\ Cl^3$, $5Sb_2\ O_3$: it is obtained by adding a large quantity of water to the chloride; used as an emetic. *Perchloride, or Pentachloride of Antimony,* $Sb\ Cl_5$, is got by passing dry chlorine over heated antimony. It is a volatile liquid.

451. **Terbromide,** $Sb\ Br_3$, is prepared as colourless crystals. **Teriodide,** $Sb\ I_3$, is a dark red body. **Tartar-emetic** $2\ [K\ (SbO)\ C_4\ H_4\ O_6\ ]\ H_2\ O$ is used medicinally (205). **Selenide of Antimony** is represented by $Sb_2\ Se_3$;

452. Tests, &c.—

1. Sulphuretted hydrogen gives a dark orange sulphide;
2. Zinc decomposes the salts in solution, throwing down the metal as a black powder.
3. Ammonia and its carbonate give a white pp.
4. Potash gives a white pp, soluble in excess.
5. Except when tartaric acid is present, water in large proportion decomposes the salts.
6. By Marsh's Test, see Arsenic.

Bismuth, and its Compounds.

453. Bismuth, Bi = 210 ; Sp. Gr. 9.79, This metal occurs *native* in Cornwall, Saxony, Bohemia, &c. It is readily obtained from the ore, by fusion. It is a brittle metal ; has a reddish white colour; fuses at 507°; somewhat volatile at a great heat; oxidises rapidly at a red heat, if exposed to air; nitric acid dissolves it freely, but hydrochloric acid scarcely at all. *Fusible Metal* contains 2 parts bismuth, 1 lead and 1 tin ; such alloy may be used for taking casts from medals, &c.

454. Oxides of Bismuth. *Bismuthic Oxide*, or *Teroxide of Bismuth*, $Bi_2 O_3$. Got anhydrous by heating basic nitrate at a low red heat. It is a yellow powder, insoluble in water, and fuses at a red heat. The hydrate $Bi HO_2$ is procured when an excess of ammonia is added to a salt of the metal. *Bismuthic Anhydride*, or *Peroxide of Bismuth* $Bi_2 O_5$. This is obtained by dropping nitrate of bismuth into a solution of caustic potash, boiling in this solution, then washing the pp., and afterwards diffusing it through a solution of potash, with chlorine passed into it. It is a red powder, $HBi O_3$; rendered anhydrous by heat.

455. Sulphide of Bismuth, $Bi_2 S_3$. This is prepared by fusion of the metal with sulphur. It has a bluish lustre. Occurs in needles, and in crystals with native sulphide of antimony, when it is called *bismuth glance*.

456. Terchloride of Bismuth, or Chloride of Bismuth, $Bi Cl_3$. This is formed by heating the metal in chlorine. It has a grey colour; was called *butter* of *bismuth*; deliquesces in air; is decomposed by a large quantity of water, into hydrochloric acid, and *oxychloride* of *bismuth*, or *pearl white* $2 (Bi Cl_3, Bi_2 O_3). H_2 O$.

457. Teriodide of Bismuth, $Bi I_3$. Got by heating bismuth and iodine. Has a dark brown colour; it is insoluble in water.

458 Nitrate of Bismuth, $Bi3 NO_3, 5H_2 O$. Nitric acid poured on powdered bismuth yields this salt. It forms prismatic crystals. If much water is added to it, a subnitrate is precipitated $2Bi NO_4, H_2 O$, formerly called *magistery of bismuth*. It is used in medicine, and frequently contains arsenic.

459. Tests, &c.—

1. Sulphuretted Hydrogen and Sulphide of Ammonium give brown or black precipitates.
2. In acid solutions of oxides, the alkalies give white precipitates.
3. Chromate of potassium gives a yellow pp..
4, Iodide of potassium gives a purple brown pp.
5. Ferrocyanide of potassium gives a greenish white pp.
6. Acid solutions are decomposed by zinc, lead, tin and cadmium.
7. Metallic button on charcoal.

Titanium, and its Compounds.

460. **Titanium.** (Ti = 50; Sp. Gr. 5.3) *Rutile* or *Nigrine*, *Anatase*, *Brookite*, *Arkansite*, *Sphene* or *Titanite*, are native compounds of this metal. It is prepared by the fusion of a mixture of rutile and carbonate of potassium.

461. **Titanic Anhydride**, $Ti\ O_2$; Anatase and Rutile are nearly pure forms of this acid. It is prepared by fusing rutile.

462. **Other Compounds of Titanium.**

Protoxide of Titanium	....	TiO.
Sesquioxide ,,	....	$Ti_2\ O_3,\ x\ H_2\ O$.
Bisulphide ,,	....	$Ti\ S_2$.
Tetrachloride ,,	....	$Ti\ Cl_4$.

463. **Tests.**

1. In acid solution ammonia gives a white pp.
2. Infusion of galls throws down an orange pp.
3. Ferrocyanide of potassium also gives an orange pp.
4. With borax, in the inner flame, a purple bead is formed.

Columbium, or Niobium, and its Compounds.

464. **Columbium** or Niobium Nb = 97·5. Found in *Tantalite*, *Columbite*, and *Norwegian Pitchblende*. Niobic Acid NbO_2 is an oxide of this metal.

Tantalum, and its Compounds.

465. **Tantalum**, Ta = 137·6, is very much like Columbium. Other compounds of Tantalum :—Protoxide of Tantalum, $Ta\ O$; Tantalic anhydride, $Ta\ O_2$; Sesquichloride of Tantalum Ta_2Cl_3; Sesquisulphide of Tantalum, $Ta_2\ S_3$.

Molybdenum, and its Compounds.

466. **Molybdenum,** $Mo = 96$. Sp. Gr. 8.6. This metal occurs in nature with sulphur, forming molybdenite; with oxygen, as molybdic ochre, and also with lead, as molybdate of lead. Can be prepared by roasting molybdenite. It is a white metal.

467. **Three Oxides** of this metal are known.—

Protoxide of Molybdenum	$Mo\,O$.
Binoxide ,, ,,	$Mo\,O_2$.
Molybdic Anhydride	$Mo\,O_3$.

468. **Other Compounds of Molybdenum** :—Protochloride of Molybdenum, $Mo\,Cl$; Bichloride of Molybdenum $Mo\,Cl_2$; Bisulphide of Molybdenum, or Molybdenite $Mo\,S_2$; Acid Molybdate of Ammonium $(H_4N)_4\,H_6\,5Mo\,O_4$.

469. **Tests** :—

1. The alkalies give brownish-black pps.
2. Ferrocyanide of potassium gives a brown pp.
3. In acid solutions, copper, zinc, and tin give a blue colouration, afterwards becoming brown.
4. With borax, in the inner flame, a brownish-red bead is produced.

Vanadium, and its Compounds.

470. **Vanadium.** $V = 137$. This is a rare and unimportant metal. It is found native in combination with lead as *vanadinite,* and also in Swedish iron ores. Obtained by the reduction of Vanadic acid by potassium. It is a silver white metal.

471. **Oxides of Vanadium**:—

Protoxide of Vanadium	$V\,O$
Binoxide ,, ,,	$V\,O_2$.
Vanadic Anhydride	$V\,O_3$.

472. **Other Compounds of Vanadium**:—Bisulphide, VS^2; Trisulphide, $V\,S_3$; Terchloride, $V\,Cl_3$; Tetrachloride, $V\,Cl_4$.

473. Tests:—

1. The fixed alkalies give a greyish pp., which becomes red on exposure to air.
2. Ferrocyanide of potassium gives a yellow pp., which becomes green on exposure to air.
3. With borax, in the inner flame, a green bead is formed.

Tungsten, and its Compounds.

474. **Tungsten,** or Wolfram, W=184. Sp. Gr. 17.6. This metal is found in nature, in combination with calcium, as *Scheelite,* from which it is generally prepared. It is a brittle metal, having a dark grey colour, and a metallic lustre when burnished.

475. There are two **Oxides** of this metal :—

Binoxide of Tungsten ....$W O_2$.
Tungstic Anhydride ....$W O_3$.

476. **Tungstic Anhydride,** or Tungstic Acid $W O_3$. Sp. Gr. 6.1. Obtained by the action of hydrochloric acid on Scheelite. It is a tasteless, yellow powder, uniting in three different forms with metals, as—

Normal tungstates ....$M_2 W O_4$.
Paratungstates ....$M_5 H, 3W_2 O_7, nH_2 O$.
Metatungstates ....$M_2, W_4 O_{13}, nH_2 O$.

477. **Other Compounds of Tungsten.** Oxychloride, $WO_2 Cl_2$; Tetrachloride, $W Cl_4$; Hexachloride, $W Cl_6$; Bisulphide, WS_2; Tersulphide, $W S_3$.

478. Tests:—

1. Not ppd. by Hydrosulphuric acid.
2. Sulphuric, nitric, and hydrochloric acids, produce white pps.
3. With borax in the inner flame, a red bead is produced.

Copper, and its Compounds.

479. **Copper,** Cu=63.5 ; Sp. Gr., 8.9. *Copper pyrites* $Cu_2 S, Fe_2 S_3$ is the most common ore from which this metal

is produced. It is also found *Native* in crystalized cubes; as *Subsulphide*, $Cu_2 S$.; as *Blue Carbonate* of *Copper*, or *Malachite* $Cu O, H_2 O, Cu CO_3$; *Red Copper ore*, *Grey Copper ore*, and *Black Oxide* of *Copper*.

In the *manufacture* of copper, after the ore has been picked and broken, it is heated in a reverberatory furnace to expel arsenic and sulphur; it is next fused in the *ore furnace*, with silicious sand, converting the sulphide of iron into silicate, or *slag*; the sulphides of copper and iron sink through the slag, forming *coarse metal*, or *matt*; the latter is run into a reservoir containing water, by which it is granulated, whilst the former is raked out through another opening; in the 3rd process, the coarse metal is roasted for 24 hours, by which a large amount of sulphide of iron is oxidised; in the 4th process the calcined product of last stage is melted with rich ores, chiefly oxides and carbonates of copper; the reaction is mainly a double decomposition between sulphide of iron and oxide of copper, forming sub-sulphide of copper, $Cu_2 S$, and a slag containing iron as silicate. It is afterwards cast into pigs; in the fifth process, the pigs are heated in a furnace to oxidise the surface, and afterwards to fuse them, by which the following reaction occurs—

$$Cu_2 S + 2Cu O = SO_2 + 4Cu$$

The copper is run into moulds, and is called *blister copper*. In the final process the copper is remelted, covered with *anthracite*, or charcoal, and stirred with the trunk of a young tree (*poled*), thus reducing and toughening the metal. The metal, when sufficiently refined, should have a fibrous structure and silky hue. It is cast in cakes.

Properties:—Copper has a red colour; is very malleable, ductile and tenacious; fusing point, 1996°; oxidises when heated to red heat in air; pure water does not oxidise it; if exposed to moist air, a green crust of hydrated oxide and carbonate is formed ; finely divided, it will burn like tinder, and form black oxide of the metal ; nitric acid dissolves the metal rapidly; hydrochloric acid will dissolve it, if exposed to air ; copper does not decompose water at a red heat.

480. *Brass* may be represented by $Cu_2 Zn$; it is an alloy of copper and zinc, and contains about 64 p.c. of the former metal. It is usually prepared by melting granulated copper with half its weight of zinc. *Muntz's patent sheathing metal* is an alloy of about 60 copper and 40 zinc ; it may be rolled hot, whereas common brass must be rolled cold. *Hard solder*, for brass, consists of 2 parts brass and 1 zinc. The following alloys contain more copper than brass :—*Tutenag*, *Tombac*, *Dutch gold*, *Similor*, *Prince Rupert's metal*, *Pinchbeck* and *Manheim gold*. *Speculum metal* consists of copper, tin, and arsenic. *Bronze* and *Bell metal* consist of copper and tin.

481. Suboxide of Copper, or Cupreous Oxide, $Cu_2 O$; Sp. Gr. 5.75. May be obtained by boiling dibasic acid acetate of copper with sugar. It has a yellow, or red colour ; it is found native as *Ruby copper*. This oxide is used to *bronze* medals, tea-urns, &c.

482. Cupric Oxide, or Black Oxide of Copper, $Cu O$; Sp. Gr. 6.5. This useful substance may be procured by dissolving copper in pure nitric acid, and decomposing the nitrate by heat. It is black and is used in organic analysis, to furnish oxygen during combustion. The hydrate is obtained by adding potash, or soda, to any of its salts. It is, at first, blue, but changes to green. Black oxide of copper dissolves in most acids, and forms salts with them.

483. Sulphides of Copper. *Subsulphide*, or *Cupreous Sulphide* $Cu_2 S$. This is made by fusing 3 parts sulphur and

8 copper. It is known as *fine metal.* It occurs in nature, as *Vitreous copper*, having a green colour. *Cupric Sulphide*, or *Sulphide of Copper*, Cu S., is formed by melting sulphur and copper. *Copper Pyrites* is a double sulphide of copper and iron, $Cu\ Fe\ S_2$. The *peacock* variety contains a larger proportion of the sulphide. The following ores contain this sulphide :—

Tennantite, Light Grey Copper ore, Silver Fahlerz, Dark Grey Copper ore, Domeykite, Arsenical Copper.

484. **Pentasulphide of Copper,** CuS_5. This is procured by the decomposition of a salt of copper, with a pentasulphide of potassium, or sodium.

485. **Phosphide of Copper,** $Cu_3\ P_2$? is got when phosphorus is boiled in sulphate of copper solution.

486. **Subchloride of Copper, Cupreous Chloride, or Dichloride,** $Cu_2\ Cl_2$, is obtained by the action of chlorine on copper filings. Finely divided, it is white; fused, it is brown; slowly cooled after heating, it is yellow. The hydrochloric acid solution absorbs oxygen from air, forming an oxychloride known as *Brunswick green*, $Cu\ Cl_2$, $3CuO.\ 4H_2\ O$.

487. **Chloride of Copper, or Cupric Chloride,** $Cu\ Cl_2$. This is obtained by heating copper filings in excess of chlorine. It is brown when anhydrous. The hydrate, which forms green prismatic crystals, is thus represented $Cu\ Cl_2, 2H_2\ O$. This salt is found native in Peru, and Chili. By mixing a strong solution of this salt, with one of ammonium, a double chloride is formed, $2H_4\ NCl,\ CuCl^2.\ 2H_2\ O$.

488. There are two **Bromides** of Copper ;—*Cupreous Bromide*, $Cu_2\ Br_2$; and *Cupric Bromide*, $Cu\ Br_2$.

489. There is *one* **Iodide**;—*Cupreous Iodide* $Cu_2\ I_2.\ H_2\ O$.

490. **Sulphate of Copper, Roman Vitriol, Blue Vitriol,** or Cupric Sulphate, $Cu\ SO_4,\ 5H_2O$; Sp. Gr., *crys.*. 2.25. This salt is extensively prepared by boiling copper in diluted sulphuric acid. It forms rhomboidal crystals, which are of a beautiful blue colour, and sometimes very large. The salt loses 4 atoms of water if heated to 212°, and is rendered

quite anhydrous at 400°. Most of the copper pigments are prepared from this salt; it is used to prevent *dry rot* in timber; for making some kinds of ink, and in dyeing and calico printing. It forms double salts with potassium, and ammonium, as *double sulphate of Copper and Potassium*, $CuSO_4$, K_2SO_4, $6H_2O$. It forms a *tribasic* sulphate as, $Cu\ SO_4, 2\ (CuO, H_2O)$. With ammonia, the *anhydrous* sulphate forms *Ammonia-Sulphate of Copper*, $Cu\ SO_4.\ 5H_3N$. With solution of sulphate of ammonia in excess, yields, *Cuprosulphate of Ammonia*, $Cu\ SO_4$, $4H_3N$, H_2O.

491. **Nitrate of Copper,** $Cu\ 2NO_3$, $6H_2\ O$, is readily procured, by dissolving copper in dilute nitric acid. It has a blue colour, and is deliquescent. If coarsely powdered, and a little water added, then folded in tin-foil, a great heat is evolved, and the metal often takes fire.

492. **Carbonates of Copper.** The *Hydrated Dibasic Carbonate*, CuO, H_2O, $Cu\ CO_3$ is obtained by adding the carbonates of the fixed alkalies to a solution of a salt of copper. *Malachite* is the natural form of this salt. *Chessylite*, found at Chessy, near Lyons, is a *blue hydrated oxycarbonate*, CuO, H_2O, $2Cu\ CO_3$. There is a double carbonate of potassium and copper, K_2CO_3, $4CuCO_3$,CuO, $10H_2O$.

493. **Tests, &c:—**

1. Sulphuretted hydrogen, and sulphide of ammonium* give a brownish black pp.
2. Ammonia in excess produces a blue solution.
3. Potash and soda give blue pps.
4. Ferrocyanide of potassium gives a red-brown pp.
5. Polished steel in copper salt solution, is coated with metallic copper, of a red colour.
6. Zinc precipitates copper, as a black powder.

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* This reagent (NH^4HS) is formed by passing Sulphuretted hydrogen through a solution of ammonia.

7. Green colour to oxidising flame.
8. In *reducing* flame, with carbonate of sodium, the metal is obtained.

Lead, and its Compounds.

494. Lead, Pb = 207; Sp. Gr., 11.36; Melting-point 617°. The most important ore is the sulphide, called *galena*, PbS. Lead is extracted from this ore by heating with lime in a reverberatory furnace, thus burning off a large portion of sulphur, and yielding the oxide, sulphate, and sulphide of lead. In this part of the operation, fusion is carefully avoided. It is afterwards melted, when sulphurous anhydride is given off, and the metal separates from the mass.

The following equations illustrate the reactions.

In the first process,

(1). $2PbS + 3O_2 = 2PbO + 2SO_2$

(2). $PbS + 2O_2 = Pb\,SO_4$.

In the second process, after the temperature of furnace is raised.

(3). $2PbO + PbS = 3Pb + SO_2$

(4). $PbS + Pb\,SO_4 = 2Pb + 2SO_2$.

Antimony and tin are separated as oxides, from the surface, when the lead is remelted. Silver is obtained from lead by melting the alloy containing it, and dipping into it as it cools, a perforated ladle; lead, in crystals, is thus separated; the process is repeated until the silver has sufficiently accumulated; lead is then removed by *cupellation*, in which it oxidises on the surface of the melted silver, and is withdrawn as a film. On an average, lead contains 10 ounces of silver to the ton.

Properties :—Lead has a bluish-white colour ; is brilliant; is malleable, and to some extent ductile; is sufficiently soft to mark paper, and to be easily cut; melts at 617° ; contracts considerably when cooled ; exposed to *dry* air, or *pure* water separately, it is *not* oxidised, but oxidises rapidly in even pure water, if in an open vessel ; as the oxide of lead is formed, the water dissolves it ; it then combines with carbonic acid in the water, forming a hydrated basic carbonate of lead $PbOH_2O, PbCO_3$, which is very insoluble ; the presence of salts in water modifies this action ; chlorides and nitrates *increase* it, whereas carbonates, sulphates, and phosphates *diminish* it. Water may, in general, be considered free from lead, if not discoloured by sulphuretted hydrogen.

Lead is used for numberless purposes, such as roofing houses, lining cisterns, forming pipes, &c., &c.

495. Protoxide of Lead or Litharge, PbO. This oxide may be prepared by heating lead in a current of air. It is obtained as a *hydrate* $2PbO, H_2O$, when an alkali is added to a salt of lead. Litharge is, to a slight extent, dissolved by water ; is fused at a little above red heat ; is a powerful base. *Massicot* is the yellow form of litharge. *Litharge of Silver* is the *paler*, and *Litharge of Gold* the redder varieties of the oxide. The oxide is used for glaze in earthenware, and with lime-water as a black dye for the hair.

496. Minium, or Red Lead is composed of the protoxide, and peroxide of lead, having generally the formula, $2PbO, PbO_2$; Sp. Gr. about 9. This is procured by heating the protoxide between 570° and 580°, *oxidising* it without fusing it. It is used for colouring common sealing wax, paper-staining, and in manufacture of flint glass.

497. **Peroxide of Lead, Binoxide of Lead, or Plumbic Acid** PbO^2. This is made as an insoluble brown powder, when minium is digested in dilute boiling nitric acid. It is a conductor of electricity; gives off oxygen at a red heat; with hydrochloric acid, yields chlorine and chloride of lead. Has weak acid properties, forming with potassium, *plumbate of potassium* $K_2 PbO_3, 3H_2 O$.

498. **Protosulphide of Lead, or Galena,** PbS. This compound is readily got by fusing lead and sulphur. It requires a bright red heat for fusion; has a bright appearance similar to pure lead; may be got by precipitating any salt of lead with sulphuretted hydrogen. *Galena* is the *natural sulphide*, found abundantly in various parts of England, in Spain, &c.

499. In reducing galena, a *subsulphide* is formed $Pb_2 S$.

500. **Chloride of Lead,** $Pb Cl_2$. This salt is most readily prepared by adding hydrochloric acid to a solution of nitrate of lead. It is soluble in boiling water; it is white; forms acicular crystals when cooled from a boiling solution. Is found *native* at Vesuvius. When the chloride is heated in air until fumes cease, an oxychloride is formed, PbO, $Pb Cl^2$. A native specimen has been found in the Mendip Hills. An oxychloride is prepared, and used, as a substitute for white lead. There is another oxychloride $Pb Cl^2$, 7PbO, which is a paint known as *patent yellow*, or *Turner's yellow*, or *Cassel yellow*.

501. **Bromide of Lead.** $Pb Br_2$, is got by precipitating a solution of lead, by hydrobromic acid. It is white and fusible.

502. **Iodide of Lead,** $Pb I_2$ is easily procured by the addition of iodide of potassium to a solution of nitrate of lead. It is a bright yellow powder. It forms double salts with the alkalies.

503. **Fluoride of Lead,** $Pb F_2$, is obtained by adding hydrofluoric acid to nitrate of lead. It is a white powder.

504. **Sulphite of Lead,** $Pb SO_3$, is a white powder, and may be prepared by digesting protoxide of lead in a solution of sulphurous acid.

505. **Sulphate of Lead,** $Pb SO_4$, is obtained when sulphuric acid, or a sulphate in solution, is added to a nitrate of lead. It is not soluble in water. It is decomposed by sulphuretted hydrogen. Is found *native* in Anglesea and Scotland, crystallised in rhombs.

506. Carbonate of Lead, White Lead, or Ceruse. $Pb CO_3$. This important compound is extensively prepared in London and Newcastle-on-Tyne. It is produced in various ways:—One of the best modern methods is to mix the oxide of lead (litharge), with water, and about 1 per cent. of neutral acetate of lead, and then to pass carbonic acid over it; the nitrate of lead is sometimes used instead of acetate. The following equations explain the reactions:—

$Pb2C_2H_3O_2 + 2PbO = Pb2C_2H_3O_2, 2PbO$ (Tribas. Acetate)
$Pb\,2C_2H_3O_2, 2PbO + 2CO_2 = Pb\,2C_2H_3O_2 + 2Pb\,CO_3$.

In the old Dutch method, still in use at Lille, thin sheets of lead are placed over gallipots, containing weak acetic acid, diluted to the extent of 2½ per cent. of strong acid, with water; the pots are then embedded in fermenting tan, at a temperature of 140° or 150°. 2 to 2½ tons of lead are converted into carbonate, by about 50lbs. strong acetic acid. In this process the air supplies oxygen, whilst the tan gives off carbonic acid; the acetic acid dissolves the oxide, forming basic or tribasic acetate, which is afterwards decomposed by the carbonic acid, forming the carbonate of lead.

This salt is generally a heavy white powder having a sp. gr. of about 6·4; it is blackened by sulphuretted hydrogen; *Clichy white*, *Krems white*, and *Silver white*, are *pure* white lead, whilst *Venice white*, *Hamburgh white*, and *Dutch white* contain *sulphate of barium*. The salt is found *native* and known as *lead-spar* or *white lead ore*.

507. Nitrate of Lead, $Pb\ 2NO_3$, may be procured by dissolving the metal, or its oxide, in hot, and dilute nitric acid. It crystallizes in anhydrous octohedra; soluble in 8 parts of water; decrepitates if heated to redness. Paper burns like a slow match, if soaked in this salt. There are three other nitrates :—the *dibasic nitrate*, *tribasic nitrate*, and *hexanitrate*.

508. Nitrites of Lead, By heating at about 160°, 1 eq. of nitrate of lead (331 parts) in solution, with 1eq. of lead (207 parts), a yellow salt is obtained, having the formula $2\ Pb\ NO_3,\ H_2\ O$. By taking 1⅓ eq. of lead instead of 1 eq., and *boiling* the mixture there is obtained orange-coloured crystals, $7PbO,\ H_2\ O,\ 2NO_4,\ 2H_2\ O$. By boiling 2 eqs. of of lead with a very weak solution, a *tetranitrate* is obtained, $Pb\ 2NO_2.\ 3PbO,\ H_2\ O$.

509. Phosphates of Lead. Each kind of phosphoric acid yields a precipitate with the soluble salts of lead. See formulæ *par.* 119. A native phosphate is found in Cumberland, Durham, Yorkshire, &c. A *chlorophosphate of lead* is also met with native $Pb\ Cl_2 .\ 3\ (Pb_3\ 2PO_4)$.

510. Cyanide of Lead Pb Cy. This is formed by adding cyanide of potassium to a solution of nitrate of lead. It is a white powder.

511. Tests, &c.—The salts are generally white, and have a sweetish taste.

1. Sulphuretted hydrogen gives a brown black pp. of the sulphide.
2. Sulphide of ammonium gives a similar pp.
3. Sulphuric acid gives a white pp.
4. Potash and Soda give a white pp. *soluble* in excess.
5. Ammonia gives a pp. *insoluble* in excess.
6. The Alkaline carbonates throw down white precipitates, insoluble in excess.
7. Iodide of potassium yields a yellow pp.
8. Before the blow-pipe, metallic lead is obtained, with a yellow ring on charcoal.

Thallium, and its Compounds.

512. **Thallium**, Tl = 204. Sp. Gr. 11·81 to 11·91. This metal is prepared from the deposits in the flues, in the preparation of Sulphur ic Acid from iron pyrites. It is a heavy metal; when freshly cut has a bluish lustre. Can be cut with the nail, hammered into foil, and made in to wire.

513. **Oxide of Thallium**, Tl_2O; is soluble in water; the solution being colourless. There is also a *Sesquioxide of Thallium*. Tl_2O_3.

514. **Other Compounds of Thallium**:—Sulphide Tl_2S; Chloride, $TlCl$; Sulphate, Tl_2SO_4; Nitrate, $TlNO_3$; Carbonate, Tl_2CO_3.

515. **Tests.**

1. The hydrated alkalies give no pp.
2. Sulphuretted hydrogen throws down a small pp.
3. Sulphide of ammonium a brownish black pp., insoluble in sulphides of alkalies.
4. Chlorides and bromides produce yellowish white pps.
5. Cyanide of potassium a white pp., soluble in excess.
6. Chromate of potassium, a pale yellow pp., insoluble in ammonia.

516. **Indium.** Little is known of this metal. Its oxide is white, insoluble in ammonia, and in acid solutions, sulphuretted hydrogen gives no pp.

Mercury, and its Compounds.

517. **Mercury, or Quicksilver** (Hg = 200; Sp. Gr. at 32°, 13.596) The metal is found generally in combination with sulphur, forming the *sulphide*, or *native cinnabar*. Sometimes it is met with *native* in small globules; it also occurs occasionally as *chloride*, *iodide* and *selenide*, and alloyed with silver. The metal is extracted from the ore, either by sublimining the sulphur, and then distilling the mercury, or by heating with quick-lime, or iron filings.

$$4HgS + 4CaO = 4Hg + 3CaS + CaSO_4.$$

This metal has been known from the earliest times; it is fluid at all ordinary temperatures, and is the only metal having this property; freezes at—39 F; it boils at about 660°, yielding a vapour with Sp. Gr. 6.976; air does not tarnish it, if pure; may be formed into a grey powder, by shaking with sulphuric acid, or water; nitric acid dissolves the metal, and forms mercuric nitrate. The metal is used to extract silver and gold from their ores; also in silvering and gilding; forms alloys with other metals, known as *amalgams*.

518. **Suboxide of Mercury, Mercurous Oxide,** Dioxide, or Black Oxide, $Hg_2 O$. This was formerly called the *protoxide*. It is procured by triturating calomel, finely levigated, with a solution of lime, potash. or soda, and washing the pp. with cold water. It is a black powder. Light or heat converts into metal and red oxide.

519. Mercuric Oxide, Nitric Oxide, Red Oxide, or Peroxide of Mercury, $Hg\ O$. When mercury is heated nearly to the boiling point with access of air, this oxide is formed as red scales. It is more easily prepared by heating the nitrate of mercury. It is poisonous; is slightly soluble in water; it turns black when heated, but resumes a red colour on cooling; forms salts.

520. Mercurous Chloride, Calomel, Subchloride, or Dichloride of Mercury, $Hg_2\ Cl$; Sp. Gr. *Solid*, 7.178. This may be obtained as a precipitate by adding a solution of common salt, to one of mercurous nitrate; or it may be procured by triturating 13 parts mercury and 17 corrosive sublimate, with a little water, until globules of mercury are not seen, and then heating the mixture, when calomel is sublimed. Calomel has no taste; is insoluble in water; when sublimed, it forms quadrilateral prisms; as a powder, it is white; nitric acid converts it into corrosive sublimate; sulphuric acid does not act on it.

521. Bichloride of Mercury, Mercuric Chloride, or Corrosive Sublimate, $Hg Cl_2$; Sp. Gr. *solid,* 5.42. This is also known as *Chloride of Mercury, Perchloride of Mercury,* or *Oxymuriate of Mercury.* In large quantities this salt is prepared by subliming a mixture of 2½ mercuric sulphate, with 1 of common salt.

$$Hg SO_4 + 2Na Cl = Na_2 SO_4 + Hg Cl_2.$$

This is a powerful poison; it has a burning and very disagreeable taste; it is met with either as a powder, or in semitransparent crystals; it dissolves in 16 parts cold and 3 boiling water; nearly insoluble in nitric and sulphuric acids; white of egg mixed with water, is an *antidote* for this poison.

522. Oxychlorides. There are three known oxychlorides obtained by the action of carbonate of potassium on corrosive sublimate; they are thus represented, (1) $2HgO, Hg Cl_2$; (2) $3HgO, Hg Cl_2$; (3) $4HgO, Hg Cl_2$.

523. The following are some of the substances produced by passing dry ammonia over heated corrosive sublimate :—

White Precipitate	$Hg H_2 NCl.$
Red Crystalline Compound	$2Hg Cl_2, Hg_3 N_2.$
Chloride of Mercuramine	$(Hg_4 H_4 N_2 O_2) Cl_2.$

524. There is a **Mercurous Bromide** Hg Br, also a **Mercuric Bromide** $Hg Br^2$.

525. Mercurous Iodide, or Subiodide, Hg I. This is a greenish-yellow powder. It may be prepared by adding iodide of potassium to the mercurous oxide salts.

Biniodide, Periodide of Mercury, or Mercuric Iodide, $Hg I_2$. This is produced when 5 parts iodine are triturated with 4 of mercury, and then sublimed. This has a beautiful red colour; is crystalline; becomes yellow when heated; the yellow is changed to red if crystals are scratched.

526. Subsulphide of Mercury, Hg_2S. This is easily obtained when sulphuretted hydrogen is passed through a solution of mercurous salt. It is a black powder; was at one time called *Ethiop's mineral.*

527. Sulphide of Mercury, Cinnabar, Bisulphide of Mercury, or Vermillion, HgS. This is the commonest ore of mercury. It is manufactured by mixing in an iron pot 6 parts mercury with 1 sulphur, and gently heating; the substance thus obtained is sublimed, which yields *vermillion*. It varies in colour, being sometimes grey, at others bright red; it is decomposed when distilled with fixed alkalies.

528. Sulphate of Mercury, or Mercuric Sulphate, $Hg\ SO_4$. On gently heating 2 parts mercury with 3 sulphuric acid, *mercurous sulphate*, or monatomic sulphate is obtained $Hg_2\ SO_4$; if the above be heated to dryness, mercuric sulphate is produced.

$$Hg + 2H_2\ SO_4 = Hg\ SO_4 + SO_2 + 2H_2\ O.$$

This is a white crystalline powder. There is a third sulphate known as *turpeth mineral*, $Hg\ SO_4$, $2HgO$. It is obtained from mercuric sulphate on adding water.

529. Mercurous Nitrate, or Normal Subnitrate, $Hg_2\ 2NO_3$, $H_2\ O$. This is procured by digesting the metal in an excess of dilute Nitric acid..

530. Mercuric Nitrate, $2\ (Hg\ 2NO_3)\ H_2O$. This is obtained in large crystals, when red oxide of mercury is dissolved by nitric acid.

531. Mercuric Carbonate, $4Hg_2O$, CO_2, is a brown-red salt, precipitated by adding carbonate of potassium to Mercuric Nitrate.

532. Mercurous Carbonate, $Hhg_2\ CO_3$, is a black or yellow powder, obtained by adding carbonate of potassium to Mercurous Nitrate.

533. Fulminate of Mercury, or Mercuric Fulminate. This is prepared by dissolving 100 grains of Mercury in an ounce and a half of nitric acid. The solution is poured into 2 ounces of alcohol, and gently warmed, when ethereal vapour is given off, and a grey powder falls, which is carefully dried at 100°. The fulminate is used in manufacture of *percussion caps*.

534. Tests, &c., *Mercurous Salts.*

1. Sulphuretted hydrogen, and sulphide of ammonium give a black pp.

2. Ferrocyanide of potassium gives a white pp.
3. Iodide of potassium gives a green pp.
4. Hydrochloric acid, and chlorides give white pps.
5. Alkaline phosphates give a white pp.

Mercuric Salts.

1. Stannous chloride gives a black pp.
2. Potash, soda, and lime give a yellow pp.
3. Sulphide of ammonium gives a black pp.
4. Sulphuretted hydrogen gives a dirty-white pp.
5. Iodide of potassium gives a scarlet pp.
6. Hydrochloric acid, and chlorides give no pp.
8. Clean copper precipitates it.

Silver, and its Compounds.

535. Silver, Ag = 108; Sp. Gr. 10.53; Fusing Pt. 1873°. This metal is sometimes found native, but generally as sulphide. Silver is separated from *argentiferous sulphide of lead*, as described *par.* 494. When the metal is obtained by *amalgamation*, the native sulphide is washed, ground, and afterwards roasted with common salt; in the roasting, arsenic and antimony are driven off, and the copper and iron are changed into oxides, chlorides, and sulphides; sulphates of sodium and chloride of silver are also formed.

$$Ag_2S + 2NaCl + 2O_2 = 2AgCl + Na_2SO_4.$$

$$CuS + 2O_2 = CuSO_4.$$

$$2CuS + 4NaCl + 4O_2 = Cu_2Cl_2 + Cl_2 + 2Na_2SO_4$$

$$2FeS_2 + 6NaCl + 7O_2 = Fe_2Cl_6 + 3Na_2SO_4 + SO_2.$$

The mass is powdered, sifted, and with water placed in casks; about ½ a ton of metal forms a charge, to which is added 1 cwt. scrap iron and afterwards 5 cwt. mercury; the casks are now made to revolve horizontally for about 20 hours, forming an amalgam. The liquid amalgam is after this run into sacks of ticking, through which the *free* mercury filters into a trough; the remaining mercury, alloyed with the silver, is driven off by distillation, in a bell-shaped furnace. The silver is then cast into ingots.

Pure silver is got, by dissolving standard silver, in dilute nitric acid, then putting into the solution a clean plate of copper; silver is precipitated, which may be washed with weak solution of ammonia, and fused.

Silver is the whitest metal known; it takes a brilliant polish; its hardness is between that of copper and gold; it may be beaten into leaves, not more than ten-thousandth of an inch thick and drawn into a wire, finer than human hair; melts at 1873°; does not oxidise in *dry*, or *moist* air; it is, however, tarnished by sulphuretted hydrogen given off by coal gas, &c.; pure water does not affect it; when cooled suddenly after fusion, it crystallizes and sends out small particles of metal, from the escape of oxygen retained in a fused state; a little copper prevents this; silver is a very good conductor of heat and electricity.

536. Silver Plating, &c. *Copper* is plated by covering it with a slip of silver, heating it nearly to fusion, and then rolling the metals together, so that they are *sweated*, or inseparably joined. *Brass* is plated, by rubbing on its surface, after it is made quite clean, a mixture of chalk, chloride of silver, and pearlash. *Steel*, by tinning its surface, and then soldering on it, silver foil. *Glass* is *silvered* by depositing on it a mixture of nitrate of silver, ammonia, carbonate of ammonium, and alcohol, with alcoholic solution of oil of cloves, and then heating for two or three hours. *Electroplating* is effected by depositing silver by galvanic battery, from a solution of cyanide of silver, in cyanide of potassium. *Dry silvering* is effected by dipping the articles in a melted *amalgam*, and expelling the mercury by heat. In *Wet silvering*, the goods are dipped in nitric acid, and afterwards water, then rubbed with a mixture of cream of tartar, chloride of silver, and corrosive sublimate.

537. **Argentous Oxide, or Suboxide of Silver,** Ag_4O. It is obtained when citrate of silver is exposed to hydrogen, at a temperature of 212°; on adding water, a brown solution is formed, from which by caustic potash the oxide is precipitated, as a black powder. When heated, is colourless; is very unstable.

538. **Argentic Oxide, or Protoxide of Silver,** Ag_2O. When a solution of potash or soda is added to the nitrate of silver, this oxide is procured. It is of a dark olive colour; has, in solution, an alkaline reaction; it is reduced to a metallic state at a dull red heat; when fused, gives a yellow colour to glass; it has no taste; is slightly soluble in water.

539 **Fulminating Silver** is produced by adding a strong solution of ammonia to the oxide of silver freshly precipitated. It forms a black powder; should be dried with great care in small quantities, for it explodes violently when rubbed or heated. It is supposed to be a *nitride* of silver.

540. **Peroxide of Silver,** Ag_2O_2. This is formed in crystals at the positive pole, when nitrate of silver is decomposed by electricity. It detonates, if mixed with phosphorus, or sulphur, and struck.

541. **Subchloride of Silver** Ag_2Cl. This is procured as black scales by digesting pure silver leaf in a solution of chloride of copper.

542. **Chloride of Silver,** $AgCl$. A solution of common salt added to one of nitrate of silver yields this salt. It

appears as a white curdy pp.; by exposure to sun's light, it assumes a violet colour. If heated to dull redness it fuses, and on cooling, has a horny appearance, and hence is called *horn silver*. At a bright red heat it fuses, and volatalises in white fumes. The chloride is reduced when heated with carbonates of the alkalies :—

$$4Ag\,Cl + 2Na_2\,CO_3 = 4Na\,Cl + 2CO_2 + O_2 + 2Ag^2.$$

The salt is met with in nature, having the name of *horn silver*; it is found both crystallized and massive.

543. Iodide of Silver, $Ag\,I$. This is readily obtained, when iodide of potassium is added to nitrate of silver in solution. It has a yellow colour, and does not dissolve in water. The *native* iodide of silver has been found in Mexico.

544. Bromide of Silver, $Ag\,Br$. This, as a yellowish substance, is thrown down when bromine, or a bromide is added to the nitrate of silver. It is insoluble in water. Is found native in Chili and Mexico.

545. Sulphide of Silver, $Ag_2\,S$. When sulphuretted hydrogen, or sulphide of ammonium is added to a solution of a silver salt, this compound is formed as a black pp. It fuses easily, forming a grey crystalline substance, giving off sulphur. *Red silver ore*, $3Ag_2\,S,\ Sb_2\,S_3$ is a double sulphide. *Silver glance* is the native sulphide.

546. There is a **Fluoride** of Silver $Ag\,F$. Got by dissolving the carbonate of silver in hydrofluoric acid.

547. Hyposulphite of Silver, $Ag_2\,S_2\,O_3,\ H_2O$. This is procured by adding a solution of nitrate of silver to one of hyposulphite of sodium. It is used in photography. It is very unstable.

548. Sulphite of Silver, $Ag_2\,SO_3$. This salt is produced in white crystals, when an alkaline sulphate is added to a silver salt solution.

549. Sulphate of Silver, $Ag_2\,SO_4$. This is yielded by the addition of sulphate of sodium to nitrate of silver, or by boiling silver in sulphuric acid. It yields a white salt, which is soluble in 90 times its weight of water.

550. Nitrate of Silver, or Lunar Caustic, $AgNO_3$. Sp. Gr. 4.33. This salt can be easily procured by the addition of nitric acid with 3 parts of water, to silver; the nitrate is formed, and nitric oxide is given off. *Lunar Caustic* is prepared, by fusing the nitrate in a silver crucible, and casting in moulds. The salt melts at 426°; the crystals dissolve in an equal weight of cold water. *Indelible*, or *Marking Ink*, is prepared by dissolving 2 parts of the nitrate, and 1 of gum, in 7 of water, and colouring the liquid with Indian ink. A solution of carbonate of sodium, and gum is used as preparatory.

551. Triphosphate of Silver, Ag_3PO_4, is got by precipitating the phosphate of sodium with nitrate of silver. The pyrophosphate ($Ag_4P_2O_7$) and metaphosphate ($AgPO_3$) are obtained similarly.

552. Cyanide of Silver, Ag Cy. Obtained as a white powder, by adding cyanide of potassium to nitrate of silver. It is insoluble in water.

553. Fulminate of Silver, $C_2N_2Ag_2O_2$. This is a very explosive substance. It is prepared by adding to 100 grains of finely powdered nitrate of silver, 1 ounce of warm alcohol, and afterwards 1 ounce of nitric acid. The powder is washed and carefully dried at 100°. It forms small white shining needles, which have a bitter taste. Is used for making *crackers*, &c.

554, Tests, &c.:—

1. A white curdy pp. with hydrochloric acid, and chlorides.
2. A brown pp. with fixed alkalies, insoluble in excess.
3. Ammonia gives a brown pp. soluble in excess.
4. A black pp. with sulphuretted hydrogen, and sulphide of ammonium.

5. Ferrous Sulphate reduces the metal.
6. Phosphate of sodium gives a yellow pp.
7. Chromate of potassium a crimson pp.
8. Salts easily reduced when heated with carbonate of sodium.

Gold, and its Compounds.

555. Gold, Au=196.6 ; Sp. Gr. 19.34; Melting Pt, 2016°. This precious metal is generally found in nature, combined with silver or copper, as *native gold.* It is mostly found either in primitive or volcanic rocks, or in the beds of rivers. Australia and California have latterly yielded the largest quantities. *Nuggets* weighing many pounds have sometimes been found. It is obtained from the ore, by grinding and washing, or by *amalgamating* with Mercury. *Pure* gold is procured by dissolving the metal with aqua regia, and evaporating the solution; dissolving the residue in water, and adding hydrochloric acid, which yields the chloride of gold; a solution of ferrous sulphate is now added, which precipitates a brown powder, $6FeSO_4+2Au\,Cl_3=2(Fe_2\,3SO_4)+Fe_2Cl_6+2Au$. This, when washed with hydrochloric acid and water, and fused with borax, yields pure gold.

It has a beautiful yellow colour ; it is so malleable that a grain may be extended over 56 square inches ; is not oxidised by exposure to either dry, or moist air ; the mineral acids do not, *separately*, act on gold ; aqua regia dissolves it ; a solution of chlorine or bromine also dissolves it ; British standard gold contains 8.33 per cent. of copper, or 11 parts of gold to 1 of copper ; the specific gravity of the alloy is 17.157 ; the standard gold of France contains 9 parts gold to 1 copper; small articles of jewelry may be tested by rubbing them on a smooth stone, and adding to the stone a drop or two of nitric acid; if gold, no change is seen, otherwise the metallic appearance is destroyed; the specific gravity is also a test; trinket-gold does not generally exceed 15; gold chains are not for most part more than 11 to 13, whilst common gilt articles are about 7 to 9.

556. **Gilding** of plaster, wood, &c., is accomplished by *gold-leaf*, which is made to adhere by *gold-size*; metals are gilt either by laying on an amalgam, or by voltaic action in a solution of cyanide of gold and potassium; another method has been introduced, in which the articles are immersed in a bath, containing a solution of gold and sesquicarbonate of potassium.

557. **Suboxide of Gold or Protoxide** Au^2O, is obtained by the addition of a solution of potash to the protochloride of gold. It has a dark colour, and is partially soluble in potash, or soda.

558. **Peroxide of Gold, or Auric Acid** Au^2O_3. Got by the decomposition of terchloride in solution, by magnesia. It is brown; light, or a temperature of 480° resolves into metallic gold and oxygen. With hydrated alkalies it forms salts, as *aurate of potassium* $K\,Au\,O_2, 3H_2O$.

559. **Protochloride of Gold,** $Au\,Cl$, is procured from terchloride, by heating it to 350°. It is very unstable; is pale yellow.

560. **Terchloride of Gold,** $Au\,Cl_3$, is obtained by adding aqua regia to gold; the solution should be gently evaporated and allowed to crystallize. It forms orange-coloured crystals; paper, or gelatin, washed with this salt and exposed to light, becomes purple, the metal being separated; protosulphate of iron reduces the salt; it is also decomposed by oxalic acid, phosphorus, charcoal, sulphurous anhydride, and gallic acid.

561. Purple of Cassius. This is procured by the gradual addition of very dilute stannous, and stannic chloride to the terchloride of gold ; it appears to have the following composition, $Sn\,Au_2, Sn_2\,O_6.\,4H_2O$, being a hydrated double stannate of gold. Acids decompose it leaving the metal. It gives a beautiful purple colour to china when mixed with borax, and applied to its surface.

562. Sulphide of Gold, or Bisulphide, $Au_4\,S_4$. This is the black pp. procured by passing sulphuretted hydrogen, through a cold solution of terchloride of gold. It is used in the gilding of china, producing the colour called *Burgos lustre.*

563. There is a **Terbromide of Gold**, $Au\,Br_3$, which closely resembles the terchloride.

There are also two **Iodides of Gold** :—**Protiodide, or Aurous Iodide**, $Au\,I$, a lemon-yellow powder, and **Teriodide, or Auric Iodide**, which is dark-green, and sparingly soluble.

564. Protocyanide of Gold, Aurous Cyanide, $Au\,Cy$, is a yellow crystalline powder, obtained by the addition of cyanide of potassium to a solution of terchloride of gold. It is used in gilding copper and silver, and more especially in electro-plating.

565. **Tricyanide of Gold, or Auric Cyanide** $Au\,Cy_3$. This compound is procured by mixing a solution of caustic potash, containing an excess of hydrocyanic acid, with terchloride of gold.

566. Tests :—

1. Brown pp., of metallic gold, with ferrous sulphate.
2. Purple of Cassius, on adding stannous or stannic chloride.
3. Mercurous nitrate gives dark-brown pp.
4. All the salts are decomposed when heated in air.

Platinum, and its Compounds.

567. Platinum, Pt = 197·1. Sp. Gr. 21·5. This metal is found combined with palladium, rhodium, osmium, iridium, copper, and iron, in the Ural Mountains, Brazil, and Peru. It is prepared by digesting the ore in aqua regia, and precipitating the platinum, in the form of ammonia chloride, by sal-ammoniac. The pp. is washed, dried, and heated to redness. by which means, spongy platinum is formed. This is made into a paste with water; pressed, dried, heated to whiteness, and then the platinum is forged by hammering it.

Platinum is a white, infusible, malleable, and ductile metal; so ductile that a wire $\frac{1}{10}$in. in diameter, will sustain a weight of 361 lbs. Ordinary acids do not act on it, but aqua regia slowly dissolves it. *Platinum black* is generally prepared by digesting platinous chloride in caustic potash. Platinum in this finely divided state, readily absorbs oxygen.

Spongy Platinum is platinum less finely divided than platinum black. It is prepared by fusing the double chloride of platinum and ammonium. It unites with sulphur, phosphorus, and arsenic. Platinum black as well as spongy platinum, readily absorbs gases.

568. **Platinous Oxide,** Pt O; is prepared by the digestion of platinous chloride, in caustic potash. It is a black powder, slowly dissolved by acids, and decomposed by heat.

569. **Platinic Oxide,** $Pt\ O_2$; is procured by the addition of a little carbonate of sodium, to nitrate of platinum. The hydrate ($Pt\ O_2$, $2H_2\ O$) thus formed is brown, the water can be expelled by heat, turning it black.

570. There are two **Sulphides of Platinum** :—**Protosulphide,** Pt S; and **Bisulphide,** $Pt\ S_2$.

571. **Platinous Chloride,** $Pt\ Cl_2$; is prepared by evaporating, and gently heating a mixture of platinum, and aqua regia. It is an olive

powder, insoluble in water, caustic potash, or hydrochloric acid dissolves it; is decomposed when heated.

572. Platinic Chloride or Bichloride of Platinum, $Pt\ Cl_4$. This salt is procured by evaporating over a water bath, platinum, dissolved in aqua regia. It is a reddish brown powder, very deliquescent the solution in water having a yellow colour; forms numerous double salts with other chlorides as:—

Double chloride of platinum and potassium...... $2KCl, Pt\ Cl_4$.
" " " sodium .... $2NaCl, Pt\ Cl_4\ 6H_2O$,
" " " ammonium ... $2H_4NCl, Pt\ Cl_4$.

573. Fulminating Platinum $Pt\ H_2 N_2, 4H_2 O$ is obtained by dissolving the chloride of platinum and ammonium in caustic soda, and adding acetic acid. It is a black powder, when heated suddenly to 400° it explodes.

574, Periodide of Platinum $Pt\ I_4$, is prepared by precipitating it from tetrachloride of platinum, by iodide of potassium. It is a brown powder.

575. Other Compounds of Platinum:—*Perbromide of Platinum,* $Pt\ Br_4$; *Fluoride of Platinum,* $Pt\ F_4$; *Platinous Iodide,* $Pt\ I_2$; *Platinic Iodide,* $Pt\ I_4$;

576. Tests:—Platinic Salts.

1. Hydrate of Potash gives a brownish-yellow solution,
2. Hydrate of Soda, a brown pp. soluble in excess.
3. Ammonia produces a yellow pp.
4. Sulphuretted hydrogen throws down a black pp.
5. Sulphide of Ammonium, also gives a black pp.

Iridium, and its Compounds.

577. Iridium, $Ir = 197{\cdot}1$ Sp. Gr. 21·15. This metal is generally found with platinum. Its principal ores are *Platiniridium*, *Osmiridium*, and *Irite*. It is prepared by heating to dull redness, a mixture of Osmiridium and fused Chloride of Sodium, both in fine powder, through which dry chlorine gas is passed. It is a whitish, brittle metal.

578. Oxides of Iridium:—The Protoxide of Iridium, $Ir\ O$; Sesquioxide of Iridium, $Ir_2 O_3$; Dioxide of Iridium, $Ir\ O_2$; Trioxide of Iridium, $Ir\ O_3$.

579. Other Compounds of Iridium :—Protochloride of Iridium, Ir Cl; Bichloride of Iridium, $Ir\ Cl_2$; Sesquichloride of Iridium, $Ir_2\ Cl_3$; Protosulphide of Iridium, Ir S; Disulphide of Iridium, $Ir\ S_2$.

580 Tests :—

1. Carbonate of potassium gives a brownish-red pp. which changes on exposure to air.
2. Protochloride of tin gives a light brown pp.
3. Chlorides of potassium, and ammonium give dark brown pps.

Palladium, and its Compounds.

581 Palladium, Pd = 106·5. Sp. Gr. from 11·4 to 11·8. This metal is found in the gold dust, and platinum ores of Brazil. Native palladium has also been met with. Prepared from the gold dust by fusing it with silver and nitre, afterwards granulating, boiling with nitric acid and water, washing, and again fusing it. The Palladium is afterwards precipitated. It is a white, ductile metal.

582. Oxides of Palladium :—Protoxide of Palladium, Pd O; Dioxide of Palladium, $Pd\ O_2$; Suboxide of Palladium, $Pd_2\ O$.

583. Other Compounds of Palladium:—Protochloride of Palladium, $Pd\ Cl_2$; Perchloride of Palladium, $Pd\ Cl_4$; Palladamine, $Pd\ H_6\ N_2\ O$; Iodide of Palladium, $Pd\ I^2$; Sulphide of Palladium, Pd S ; Sulphate of Palladium, $Pd\ SO^4$.

584. Tests:—

1. Carbonate of potassium gives a brownish pp. sol. in excess.
2. Sulphuretted hydrogen and sulphide of ammonium throw down a black pp.
3. Iodide of potassium gives a black pp.
4. Cyanide of mercury produces a yellowish white pp.

Rhodium, and its Compounds.

585. Rhodium, Ro = 104.3. Sp. Gr. 12.1. Rhodium is also found associated with native platinum, from which it is prepared. It is a greyish, brittle, metal.

586. Oxides of Rhodium :—Protoxide of Rhodium, Ro O ; Sesquioxide of Rhodium, $Ro_2\ O_3$.

587. Other Compounds of Rhodium :—Terchloride, $Ro\ Cl_3$; and Sesquichloride, $Ro_2\ Cl_3$ of Rhodium. Chloride of Rhodium and Sodium $3Na\ Cl,\ Ro\ Cl_3,\ 9H_2O$,

588. Tests :—

1. Ammonia throws down a yellowish pp.
2. Protochloride of tin gives a dark red-brown colour.
3. Chlorides of potassium and ammonium throw down pink pps,

Ruthenium, and its Compounds.

589. Ruthenium, Ru = 104.2. Sp. Gr. from 11 to 11.4. Found in the platinum ores in America and Russia, also with iridium and osmium. It is generally obtained from osmiridium. It is a hard and brittle metal.

590. Oxides of Ruthenium :—

Protoxide of Ruthenium	Ru O.
Sesquioxide ,,	$Ru_2\ O_3$.
Binoxide ,,	$Ru\ O_2$.
Ruthenic Anhydride	$Ru\ O^3$.

591. Other Compounds of Ruthenium :—

Bichloride of Ruthenium	$Ru\ Cl_2$.
Terchloride ,,	$Ru\ Cl_3$.
Sesquichloride ,,	$Ru_2\ Cl_3$.

592. Tests :—

1. The alkalies and their carbonates give brown pps. sol. in excess.
2. Hydrosulphuric acid produces a dark brown pp.
3. Cyanide of mercury gives a blue pp.

Osmium, and its Compounds.

593. **Osmium.** Os = 199 Sp. Gr. 21.4. Found in nature in combination with Iridium, as Ormiridium from which it is obtained. It is a grey, brittle metal.

594. **Oxides of Osmium :**

Protoxide of Osmium	$Os\ O$.
Sesquioxide ,,	$Os_2\ O_3$.
Binoxide ,,	$Os\ O_2$.
Osmious anhydride	$Os\ O_3$.
Osmic acid	$Os\ O^4$.

595. **Other Compounds of Osmium:—**

Protochloride of Osmium	$Os\ Cl_2$.
Trichloride ,,	$Os\ Cl^3$.
Osmic Subchloride	$Os\ Cl^4$.

596. **Tests:—**

1. The alkalies, on boiling, give black pps.
2. Sulphuretted hydrogen throws down a brownish-yellow pp.
3. Chloride of tin produces a brownish pp.
4. Subnitrate of mercury gives a yellowish-white pp.

Weights and Measures.

APOTHECARIES' WEIGHT.

Pound		Ozs.		Drachms		Scruples		Grains		Fr. Grammes.
1	=	12	=	96	=	288	=	5760	=	372·96
		1	=	8	=	24	=	480	=	31·08
				1	=	3	=	60	=	3.885
						1	=	20	=	1.295
								1	=	0.0647

AVOIRDUPOIS WEIGHT.

Pound		Ozs.		Drachms		Grains		Fr. Grammes.
1	=	16	=	256	=	7000	=	453·25
		1	=	16	=	437.5	=	28.328
				1	=	27·343	=	1.77

IMPERIAL MEASURE.

Gallon		Pints		Fluid Ozs.		Fluid Drms.		Minims.
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

WEIGHT OF WATER AT 62°, CONTAINED IN THE IMP. GAL. &c.

1 Imperial Gallon = 70000 Grains
1 „ Pint = 8750 „
1 „ Fluid Ounce = 437.5 „
1 „ Fluid Drachm = 54.7 „
1 „ Minim = 0·91 „

CUBIC INCHES IN THE IMPERIAL GALLON, &c.

1 Imperial Gallon = 277.276 Cu. In.
1 „ Pint = 34.659 „
1 „ Fluid Ounce = 1.7329 „
1 „ Fluid Drachm = 0.2166 „
1 „ Minim = 0.0036 „

FRENCH WEIGHTS AND MEASURES.

MEASURES OF LENGTH.

	En. In.	Mil.	Fur.	Yds.	Feet.	In.
Millimetre	·03937					
Centimetre	·39371					
Decimetre	3·93710					
Metre	39·37100					
Decametre	393·71000	0	0	10	2	9·7
Hectometre	3937·10000	0	0	109	1	1
Kilometre	39371·00000	0	4	213	4	10·2
Myriometre	393710·00000	6	1	156	0	6

MEASURES OF CAPACITY.

					English Imp. Meas.			
		Cubic In.		Gall.	Pints	F. Oz.	F. Dr.	Min.
Millilitre	=	·06102	=	0	0	0	0	16·3
Centilitre	=	·61028	=	0	0	0	2	43
Decilitre	=	6·10280	=	0	0	3	3	2
Litre	=	61·02800	=	0	1	15	1	43
Decalitre	=	610·28000	=	2	1	12	1	16
Hectolitre	=	6102·80000	=	22	0	1	4	48
Kilolitre	=	61028·00000	=	220	0	12	6	24
Myriolitre	=	610280·00000	=	2200	·7	13	4	48

UNIT = 1 Cubic Metre.

			Cu. Metre.
Cubic Millimetre	=		0·000,000,001
Cubic Centimetre	=		0·000,001
Cubic Decimetre	=	1 Litre =	0·001
Cubic Metre	=		1.
Cubic Decametre	=		1,000·0
Cubic Hectometre	=		1,000,000·0
Cubic Kilometre	=		1,000,000,000·0

One Litre of Hydrogen weighs 0·0896 Gramme.

MEASURES OF WEIGHTS.

			Avoirdupois.		
		Eng. Grains.	Lbs.	Oz.	Drms.
Milligramme	=	·0154			
Centigramme	=	·1543			
Decigramme	=	1·5432			
Gramme	=	15.4323			
Decagramme	=	154·3234	0	0	5·65
Hectogramme	=	1543·2348	0	3	8·5
Kilogramme	=	15432·3480	2	3	5
Myriogramme	=	154323·4800	22	1	2

TABLE FOR CONVERSION OF DEGREES ON CENTIGRADE TO FAHRENHEIT'S SCALE.

°Cent.	°Fah.	°Cent.	°Fah.	°Cent.	°Fah.	°Cent	°Fah.	°Cent.	°Fah.
—50	—58.0	— 9	15.8	32	89.6	73	163.4	114	237.2
—49	—56.2	— 8	17.6	33	91.4	74	165.2	115	239.0
—48	—54.4	— 7	19.4	34	93 2	75	167·0	116	240.8
—47	—52.6	— 6	21.2	35	95.0	76	168.8	117	242.6
—46	—50.8	— 5	23.0	36	96.8	77	170.6	118	244.4
—45	—49.0	— 4	24.8	37	98.6	78	172.4	119	246.2
—44	—47.2	— 3	26.6	38	100.4	79	174.2	120	248.0
—43	—45.4	— 2	28.4	39	102.2	80	176.0	121	249.8
—42	—43.6	— 1	30.2	40	104.0	81	177.8	122	251.6
—41	—41.8	0	32.0	41	105 8	82	179.6	123	253.4
—40	—40.0	+ 1	33.8	42	107.6	83	181.4	124	255.2
—39	—38.2	2	35.6	43	109.4	84	183 2	125	257.0
—38	—36.4	3	37.4	44	111.2	85	185.0	126	258.8
—37	—34.6	4	39.2	45	113.0	86	186.8	127	260.6
—36	—32.8	5	41.0	46	114.8	87	188.6	128	262.4
—35	—31.0	6	42.8	47	116.6	88	190.4	129	264.2
—34	—29.2	7	44.6	48	118.4	89	192.2	130	266.0
—33	—27.4	8	46.4	49	120.2	90	194.0	131	267.8
—32	—25.6	9	48.2	50	122.0	91	195.8	132	269.6
—31	—23.8	10	50.0	51	123.8	92	197.6	133	271.4
—30	—22.0	11	51.8	52	125.6	93	199.4	134	273.2
—29	—20.2	12	53.6	53	127.4	94	201.2	135	275.0
—28	—18.4	13	55.4	54	129.2	95	203.0	136	276.8
—27	—16.6	14	57.2	55	131.0	96	204 8	137	278.6
—26	—14.8	15	59.0	56	132.8	97	206.6	138	280.4
—25	—13.0	16	60.8	57	134.6	98	208.4	139	282.2
—24	—11.2	17	62.6	58	136.4	99	210.2	140	284.0
—23	— 9.4	18	64.4	59	138.2	100	212 0	141	285.8
—22	— 7.6	19	66.2	60	140.0	101	213.8	142	287.6
—21	— 5.8	20	68.0	61	141.8	102	215.6	143	289.4
—20	— 4.0	21	69.8	62	143.6	103	217.4	144	291.2
—19	— 2.2	22	71.6	63	145.4	104	219.2	145	293.0
—18	— 0.4	23	73.4	64	147.2	105	221.0	146	294.8
—17	+ 1.4	24	75.2	65	149.0	106	222.8	147	296.6
—16	3.2	25	77.0	66	150.8	107	224.6	148	298.4
—15	5.0	26	78.8	67	152.6	108	226.4	149	300.2
—14	6.8	27	80.6	68	154.4	109	228.2	150	302.0
—13	8.6	28	82.4	69	156.2	110	230.0	151	303.8
—12	10.4	29	84.2	70	158.0	111	231.8	152	305.6
—11	12.2	30	86.0	71	159.8	112	233.6	153	307.4
—10	14.0	31	87.8	72	161.6	113	235.4	154	309.2

Showing the behaviour of Solutions of Metals with Sulphuretted Hydrogen (H_2S) Sulphide of Ammonium (H_4NHS), and Carbonate of Ammonium, employed successively. (Dr. Will.)

Elements ppd from their acid solutions by Sulphuretted Hydrogen, as sulphides		Bodies ppd. by Sulphide of Ammonium.			Bodies not ppd. by Sulphuretted Hydroge or Sulphide of Ammonium.	
Soluble in Sulphide of Ammonium, and reprecipitated by Hydrochloric Acid.	Insoluble in Sulphide of Ammonium. (H_4NHS)	As Sulphides.	As Oxides.	As Salts.	In the presence of Muriate of Ammonium, on addition of Carbonate of Ammonium are	
					ppd.	not ppd.
Antimony Orange	Mercury Silver Lead Bismuth Copper } Black or Brownish Black.	Nickel Cobalt } Black.	Aluminum Glucinum Chromium } Soluble in Potash.	Baryta, Strontia, Lime, in combination with phosphoric, boracic, oxalic, & some other acids.	Barium.	Magnesium.
Arsenic Tin } Yellow	Cadmium Yellow.	Manganese } Flesh coloured	Thorinum Yttrium Cerium Zirconium Titanium Tantalum } Insoluble in Potash.	Magnesia, in combination with phosphoric acid.	Strontium	Potassium.
Gold Platinum Iridium } Black.	Palladium Rhodium Osmium } Brownish black.	Iron Black.			Calcium	Sodium.
Molybdenum Brown.		Zinc White.				Lithium.
		Uranium } Brownish black.				Ammonium.

EXERCISES.

1.—Give the meaning of the following Symbols :—

H, S, O, C, P, Si, Cl, I, B, Br, N, F.

2.—Write the meaning of these Symbols :—

K, Na, Pb, Fe, Ag, Au, Ba, Al, As, Mg, Mn, Ca, Bi, Hg, Cu, Pt, Ni, Co, Sr, Zn, Sn, Sb, Cd, Li.

3·—Represent by symbols the following oxides :—

Black Oxide of Copper, Black Oxide of Iron, Sesquioxide of Iron, Sesquioxide of Chromium, Potash, Soda, Peroxide of Manganese, Protoxide of Nickel, Mercurous Oxide, Stannic Oxide, Alumina, Baryta, Strontia, Lime, Magnesia.

4.—Write the symbols for these Acids and Anhydrides:—

Nitric Acid, Sulphuric Acid, Phosphoric Anhydride, Carbonic Anhydride, Hydrochloric Acid, Chloric Acid, Sulphurous Anhydride, Nitrous Acid, Arsenious Anhydride, Chromic Acid, Boracic Acid, Silicic Acid, Arsenic Acid, Oxalic Acid, Hydrofluoric Acid, Hydrobromic Acid, Hydriodic Acid, Hydrosulphuric Acid.

5.—Write out the names of the following salts:—

$K\,NO_3$; $Ag\,NO_3$; $HgNO_3.\ H_2O$; $K_2\,CO_3.H_2O$; $KH\,CO_3$; $Ca\,CO_3$; $Ba\,Ca\,2CO_3$; $2(H_4N)_2\,CO_3.\ CO_2$; $Cu\,2NO_3.\ 6H_2O$; $Cu\,2NO_3,\ 3Cu\,H_2O_2$; $3HgNO_3.\ Hg\,HO.$; $Mg\,2NO_3.\ 6H_2O$; $Cu\,CO_3,\ CuH_2\,O_2$.

6.—Write the symbols for these compounds:—

Malachite, Galena, Potash Alum, Nitre, Cinnabar, Epsom Salts, Spirit of Salts, Calomel, Gypsum, Dolomite, White Copperas, and Blue Copperas.

7.—Give the Atomic weights of:—

O, S, P, H, Cl, Cu, Fe, N, F, C, I, Br, Na, K, Pb, Al, Sn, Ca, Pt, Hg, Sr, Ba, Mg, Ni, Co, Mn, Zn.

8—Find the proportion of each element in 10lbs. of Carbonic Anhydride:—

$C = 12$; $O = 16$.

9.—In one pound (Avoir.) of the Chloride of Sodium, find the weight of each element:—

$Cl = 35.5$; $Na = 23$.

10.—Find the percentage of each element in the following compounds:—

Sulphide of Copper, Bisulphide of Sodium, and Copper Pyrites. *See Atomic Weights, par.* 25.

11.—Show, by a *diagram*, the reactions in the preparation of Oxygen, 5th method; Hydrogen, 1st method; and Ammonia.

12.—When two ounces (Avoir.) of Chlorate of Potassium are heated, calculate what weight of Oxygen should be obtained.

13.—Write the names of these compounds:—

Bi_2S_3; Au_4S_4; SO_3; H_2SO_4; HCl; P_2O_5; H_3P. $SrCO_3$; $SrClO_3$; $Na\ ClO_3$; Ag_2SO_3; $NaH\ SO_3.\ 4H_2O$; $2Cu\ CO_3.\ Cu\ H_2\ O_2$; $Fe\ S_2$; $Mg\ Ca\ 2CO_3$.

14.—*Explain* the reaction represented by this *equation*:—

$$2Zn\ SO_4 = 2ZnO + 2SO_2 + O_2.$$

15.—Define these terms:—

Anhydride, Acid, Base, Salt, Atom, Molecule, and Salt Radicle.

16.—Find the percentage composition of—

$Ca\ CO_3$; $Mg\ CO_3$; KCl; and Hg_2S.

17.—Find the weight of each element in one pound (Avoir.):—

$2Na_2\ CO_3,\ H_2\ CO_3.\ 3H_2O$ (Trona).

18.—Write the Names for these Compounds:—

$Cr_2\ Cl_6$; $Mn_2\ Cl_6$; $PbSO_3$; $H\ SO_3$; $3Ag_2S$, Sb_2S_3; $2LiClO_3 + H_2O$; $MnSO_4$; $KHSO_3$; $Zn\ SO_4$.

19.—How many litres of oxygen should be obtained from 3 ounces of Chlorate of Potassium ?—

20.—Calculate the per centage of each element in the following compounds :—

$K_2 CO_3$; $Na HCO_3$; $Pb SO_4$, and $Na PO_3$.

21.—Explain the chemical reactions represented by the following equations:—

(1). $H_4N NO_3 = 2H_2 O + N_2O$.

(2). $3Fe + 4H_2O = FeO, Fe_2O_3 + 4H_2$.

(3). $2 Zn SO_4 = 2 Zn O + 2SO_2 + O_2$.

22.—How many grammes of nitrous oxide and water should 100 grammes of nitrate of ammonium yield ?—

23.—What weight of oxygen would fill a globe holding 20 litres at 50° F.?

24.—Find the per centage composition of:—

$Ag PO_4$; $KHSO_4$; and $Ba Cl_2 . 2H_2O$.

25.—Explain the chemical reactions represented by these equations :—

(1). $Fe S + H_2 SO_4 = H_2S + FeSO_4$

(2). $H_4N NO_2 = 2H_2O + N_2$.

(3). $CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$.

26.—Give synonyms for these names:—

Cupric Acetate, Plumbic Nitrate, Bismuthic Oxide, Zincic Oxide, Cobatic Oxide, Cobaltic Peroxide, Manganic Anhydride, Manganous Sulphate, Ferric Anhydride, Ferrous Iodide, Aluminic Hydrate, Magnesic Sulphate, Hydric Perchlorate, Hydrate Chlorate, Potassic Iodide, Potassic Chloride.

27.—Give synonyms for these names:—

Potassic Cyanide, Potassic Tartrate, Sodic Oxide, Sodic Hydrate, Sodic Sulphate, Hydrosodic Carbonate, Sodic Sulphite, Sodic Chloride, Sodic Silicate, Ammonic Chloride, Ammonic Nitrate, Hydro Ammonic Sulphide, Baric Peroxide, Baric Hydrate, Baric Carbonate, Strontic Nitrate, Strontic Sulphate, Calcic Chloride.

28.—Write the formulæ for the following substances:—

Nitrous Anhydride, Nitric Anhydride, Hydric Nitrate, Hyponitric Anhydride, Ammonic Oxide, Heavy Carbide of Hydrogen, Light Carbide of Hydrogen, Hydric Sulphate, Hydric Sulphide, Sulphurous Anhydride, Sulphuric Anhydride, Hydric Hypo-phosphite, Hydric Phosphite, Trihydric Phosphate, Dihydric Diphosphate, Hydric Chlorate, Hydric Perchlorate, Hypochloric Anhydride.

29.—Represent the following Equations by Diagrams:—

(*a*). $2\ (HgO) + 4Cl = HgO,\ HgCl_2 + Cl_2\ O.$

(*b*). $2\ (SO_2) + N_2O_4 + 2\ (H_2O) = 2\ (H_2SO_4) + 2\ (NO).$

(*c*). $2\ (NH_3) + 3\ Cl_2 = 6\ (HCl) + N_2.$

(*d*). $3\ (K_2CO_3) + 6\ Cl = 5\ (KCl) + 3\ (CO_2) + KClO_3.$

30.—Calculate the percentages in these substances:—

$Al_2\ 3\ (SO_4),\ K_2SO_4,\ 24\ H_2O;\ Fe_2\ (SO_4)_3,\ 7\ H_2O;$

$Mn\ SO_4,\ 7\ (H_2O);\ Cr_2O_3,\ 4\ (H_2O);\ Cu\ (NO_3)_2,\ 3H_2O$

31.—Give the formulæ of these percentages:—

(*a*). Ba = 56·16. Cl = 29.09. H = 1·64. O = 13·11.

(*b*). Na = 14·29. S = 9·93. O = 69·57. H = 6·21.

(*c*). Ca = 23·26. S = 18·60. O 55·81. H = 2·33.

32.—Show by equations the chemical changes when

(1) Dry chlorine is passed over nitrate of silver.
(2) Nitric acid is added to chalk.
(3) Sal-ammoniac and potash are heated together.
(4) Sulphuric acid is heated with common salt.

33.—Calculate the percentage composition of

(1) Blue carbonate of copper.
(2) Chlorate of magnesium.
(3) Potash alum.

34.—How much sal-ammoniac will yield a kilogramme of ammonia?

35.—Give the formulæ for the following percentages:—

(*a*). $Sr = 32.84$. $Cl = 26.64$. $H = 4.50$. $O = 36.02$.
(*b*). $Ca = 24.54$. $H = 2.45$. $P = 19.02$. $O = 53.99$.
(*c*). $Co = 20.99$. $S = 11.39$. $H = 4.98$. $O = 62.64$.

36.—State in cubic centimetres how much nitrogen is set free in the combustion of 20 cu. c. of ammonia.

37.—Express in grammes, how much copper and nitric acid should be used to obtain 50 litres of nitric oxide, at the ordinary temperature and pressure.

38.—What volumes of oxygen and nitrogen would be respectively procured by the decomposition of 10 litres of laughing gas ?

39.—Calculate the formulæ for these percentages:—

(*a*). $Cu = 25.45$. $S = 12.83$. $O = 57.72$. $H = 4.00$
(*b*). $Al = 8.25$. $S = 14.39$. $O = 71.97$. $H = 5.39$.
(*c*). $Na = 18.55$. $S = 25.81$. $O = 51.61$. $H = 4.03$.

40.—Explain the reactions indicated in these equations:—

(1) $2H_3N + 3Cl_2 = 6\,HCl + N_2$.
(2) $2NaI + MnO_2 + 2H_2SO_4 = Na_2SO_4 + MnSO_4 + 2H_2O + I_2$.
(3) $NaCl + H_2SO_4 = HCl + NaHSO_4$.
(4) $2NaC_2H_3O_2 + BaO, H_2O = BaCO_3 + Na_2CO_3 + 2CH_4$.

41.—Find how many pints of hydrochloric acid, and how many ounces of manganese, should be used to yield 100 litres of Chlorine (at 0°C, and 0m. 76 Bar.)

42.—Calculate the percentage composition of:—

$MgCl_2.\ 6H_2O;\ ZnSO_4\ 7H_2O;\ Ag_3PO_4.$

43.—Give the formulæ for the following per centages :—

(*a*). $N = 22.58$ $H = 6.46$. $C = 19.36$. $O = 51.60$.
(*b*). $K = 13.86$. $Na = 8.15$. $C = 17.02$. $H = 4.25$. $O = 56.72$.
(*c*). $Cu = 14.38$. $S = 14.49$. $O = 50.71$. $K = 17.70$. $H = 2.72$

44.—Explain what occurs,

(1) When hydrochloric acid is added to sesquioxide of iron.

(2) When manganese, common salt, and oil of vitriol, are mixed and gently heated.

(3) When carbonate of potassium and half its weight of lime, with water sufficient, are boiled.

45.—Give the formulæ for Glance Cobalt, Red Prussiate of Potash, Trona Sal-ammoniac, Heavy Spar, Celestine, Iceland Spar, Cryolite, Calamine, Borax.

46.—*A Salt has been found to contain in 100 parts

H, 3·18; O, 33·88 ; N, 14·84; S, 16·95; Ni, 31·15.

What is the Formula of the Salt ?

Give such details as will show the mode of Calculation.

$O = 16, H = 1, N = 14, S = 32, Ni = 58·8.$

47.—*Describe and represent in Equations the several stages of the Manufacture of Phosphorus.

48.—How many pounds of Silver are necessary to prepare 50lbs. (Avoir.) of Nitrate of Silver?

$O = 16; N = 14; Ag = 108.$

49.—Give the Composition of HCl, H_2O, and of NH_3 by weight and volume, and state the specific gravities of these three compounds referred to Hydrogen.

$H = 1 ; O = 16 ; N = 14 ; Cl = 35·5.$

50.—*The Formula of Crystallized Carbonate of Sodium is $NaCO_3 + 10H_2O$. What is its per centage Composition ?

$H = 1 ; O = 16 ; C = 12 ; Na = 23.$

51.—*How many pounds of Copper are necessary to prepare 100 pounds of Crystallized Sulphate of Copper, $Cu\,SO_4 + 5H_2O$?

$H = 1 ; O = 16 ; S = 32 ; Cu = 63·36.$

52.—*A Substance has been found to consist of Calcium, Phosphorus, and Oxygen in the following proportions :—

$$Ca, 38{\cdot}71 ;\ P, 20.00 ;\ O, 41.29.$$

$$Ca = 40 ;\ P = 31 ;\ O = 16.$$

What is the Formula of the Substance ?

53.—*100 parts of Peroxide of Manganese contain 36·7 parts of Oxygen. How many parts of Oxygen may be obtained from the Peroxide by the action of heat alone, and how many by the action of Sulphuric Acid?

$$Mn = 55{\cdot}2 ;\ O = 16.$$

54—*The specific gravity of Nitrogen referred to that of Hydrogen is 14. What is the specific gravity of Ammonia referred to that of Hydrogen as unity ?

55.—Write the formula for this compound:—

$$K = 8.23.\ Al = 5.79.\ S = 13.49.\ O = 67.43.\ H = 5.06.$$

56.—Give the *tests* for ammonia, sulphuric acid, nitric acid, chlorine, baryta, and copper?

57.—Explain the reactions represented by these equations :—

(1). $3CaO + 12S + H_2\,O = 2Ca\,S_5 + Ca\,S_2H_2O_4.$

(2). $Ba_2\,SO_4 + 2Ca\,Cl = Ca_2\,SO_4 + 2Ba\,Cl.$

(3). $Sb_2\,S_3 + 6HCl = 2Sb\,Cl_3 + 3H\ \ S.$

(4). $Cu + 2H_2\,SO_4 = Cu\,SO_4 + SO_2 + 2H_2\,O.$

58.—Name the principal *ores* of lead, iron, copper, mercury, barium, arsenic tin, antimony, and zinc.

59.—Explain the terms *monatomic*, *diatomic*, *triatomic*, and *tetratomic*.

60.—Find the weight of 20 litres of marsh gas at 0° C (32° F), and 760 millimetres pressure.

61.—Calculate the percentages of the following compounds :—

$Cd\,2NO_3.\,4H_2O$; $K\,Mn\,2SO_4.\,12H_2O$; $(Ca\ Mg\ Fe\ Mn)\,O, Si\,O_2.$

62.—Express in grammes, the weight of carbonate of calcium necessary to yield 50 litres of carbonic anhydride, at 10° C, and 760 mm. pressure.

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*Government Science Examination Questions.

63.—How much air is necessary for the entire combustion of 100 grammes of carbon?

64.—Describe *Marsh's* and *Reinch's* tests.

65.—How many cwts. of sulphuric acid, containing 70 per cent. of H_2SO_4, would be required to produce 10 tons of salt-cake?

66.—How may the *ferrous* and *ferric* salts be distinguished?

67.—If 5000 litres of olefiant gas are consumed in a room containing 500 cubic metres of dry and pure air, both at 10° C and 760 mm., what is the percentage composition of the air at the close, providing nothing escapes?

68—Describe the chemical reactions when—

(1). Hydrochloric acid is added to Baryta.
(2). Phosphorus is boiled with baryta and water.
(3). *Bauxite* is heated with carbonate of sodium.
(4). Sulphite of sodium is boiled with sulphur.

69.—Explain these equations:—

(1). $6BaS + 6H_2O + 8CuO = 5(BaO\ H_2O) + BaS\ H_2O_4 + 4Cu_2S.$
(2). $3(CoO, H_2O) + Cl_2 = Co_2O_3, 3H_2O + CoCl_2.$
(3). $2KBrO_3 + 6H_2S = 2KBr + 6H_2O + 3S_2.$

70.—Calculate the percentage composition of:—

$ZnSO_4.\ 7H_2O$; $MgO, SiO_2.\ 2MgO, 3SiO_2$; $KAl\ 2SO_4, 12H_2O.$

71.—Represent these equations by the New Notation:—

(*a*). $MnO_2 + NaCl + 2(HO, SO_3) = MnO, SO_3 + NaO, SO_3 + 2HO + Cl.$
(*b*). $3(KO, ClO_5) + 2(HO, SO_3) = 2(KO, SO_3) + KO, ClO_7 + 2ClO_4 + 2HO.$
(*c*). $NaCl + HO, SO_3 = NaO, SO_3 + HCl.$

72.—What is the per centage Composition of:—

$AgNO_3$; $Sb_2O_5, 4(H_2O)$; $CuC_2H_3O_2$, $Cu(NO_3)_2, 3(H_2O)$?

73.—Find the per cantage of each element in these Compounds :—

$$Pb\,CO_3 ;\ Pb\,(C_2\,H_3\,O_2)_2,\ 3(H_2O) ;\ Bi\ (NO_3)_3,\ 10(H_2O) ;\ Cd\ (NO_3)_2.$$

74.—*One Gramme of P. is to be converted into the Pentachloride of Phosphorus. How many litres of Cl at (0°C, and 0^m .76 Bar) are required, and how many grammes of Binoxide of Manganese and liquid Hydrochloric Acid (containing 20 p. c. of Anhydrous Acid) are necessary to evolve this quantity of Chlorine ?

75.—*Give the Formulæ of Ammonia and Phosphoretted Hydrogen, the percentage composition of these Compounds by weight and by volume, and their specific gravities.

76.—*One Litre of Olefiant gas of 0° C and $0^{m.}$76 Bar. is to be completely burned by Oxide of Copper (CuO). How many grammes of Oxide of Copper are required and how many litres of Carbonic Acid are produced ? Give such numerical details as will show the mode of calculation.

$$H = 1 ;\ C = 12 ;\ Cu = 63{\cdot}5 ;\ O = 16.$$

77.—*45·3 parts by weight of dry pure Carbonate of Sodium, are fused with 54·7 parts by weight of Sulphur, air being carefully excluded. Express the reaction which takes place, and the products which are formed, in an equation.

78.—*The Iodine in 100 volumes of Hydriodic Acid is liberated in succession by Chlorine and by Oxygen. How many volumes of Chlorine and how many volumes of Oxygen are required ?

79.—How many litres of gaseous Ammonia are necessary to neutralise 20 grammes of Hydrochloric Acid Gas ?

80.—Explain the chemical changes in the ordinary methods of manufacturing phosphorus, and oil of vitriol.

81.—In passing 5 litres of gaseous hydrochloric acid over hot iron, what volume of hydrogen may be obtained ?

82.—What weight in grammes, of pure Manganese should be used to obtain 5 grammes of Chlorine ?

83.—What compound would be formed by burning Phosphorus in Chlorine and what *volume* of the compound gas would be the result, providing 5 litres of Chlorine are used ?

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* Government Science Examination Questions.

84.—What volume of Chlorine can 10 litres of Phosphuretted Hydrogen take up?

$$PH_3 + 4Cl_2 = PCl_5 + 3HCl.$$

85.—If 20 grms. of Silica are used to produce the fluoride of Silicon, what is the volume of the gas?

$$Si\,O_2 + 4HF = Si\,F_4 + 2H_2O.$$

86.—Give the volume of Nitric Oxide required in the complete combustion of 5 grms. of Bisulphide of Carbon?

$$CS_2 + 6NO = 3N_2 + CO_2 + 2SO_2.$$

87.—How many litres of Hydriodic Acid would unite with 10 litres of Phosphuretted Hydrogen?

$$PH_3 + HI = PH_4\,I.$$

88.—What is obtained by saturating Phosphorus with Chlorine, and what would be the volume of its vapour at 0° C. and 760 mm. providing 5 grms. of Phosphorus were used?

89.—Explain the reactions indicated by these Equations:—

(1) $2PH_3 + 4O_2 = P_2O_5 + 3H_2O.$
(2) $CO\,Cl_2 + H_2O = CO_2 + 2HCl.$
(3) $KC_2H_3\,O_2 + KHO = CH_4 + K_2CO_3.$

90.—Express by *Equations* the chemical changes which take place:—

(1) By the action of HNO_3 upon HKO.
(2) By the combustion of bisulphide of carbon in oxygen.
(3) By heating MnO_2 with HCl, and conducting the gas produced, into KI in solution.

91.—Explain the reactions expressed by the following Equations:—

(1) $Ca\,CO_3 + H_2SO_4 = Ca\,SO_4 + CO_2 + H_2O$
(2) $SO_2\,Cl_2 + 2H_2O = H_2SO_4 + 2HCl.$
(3) $SO_2 + 2KHO = K_2SO_3 + H_2O.$

92.—Find how many cubic centimetres of Carbonic Acid and Nitrogen, are respectively given off in the combustion of 10 grms. of gunpowder.

93.—Explain these Equations :—

(1) $2Sb + 2HgCl_2 = SbCl_3 + SbHg + HgCl$.
(2) $Hg\,Cl_2 + Sn = Sn\,Cl_2 + Hg$.
(3) $Cu_2S + 2CuO = SO_2 + 4Cu$.
(4) $2FeS_2 + 3O_2 = 2FeS + 2SO_2$.
(5) $7P + 7CaO = Ca_2\,P_2\,O_7 + 5CaP$.

94.—Calculate the percentage composition of Chloride of Lime, Sesquicarbonate of Ammonium, and Stannate of Potassium.

95.—Describe the chemical reactions when

(1) Cl is passed through CoO, H_2O and water.
(2) $Mg\,2NO_3.\,6H_2O$ is heated to redness.
(3) $Sn\,Cl_2$ is boiled in solution, with $Fe_2\,O_3$, H_2O.
(4) The following mixture is distilled: $Ca\,F_2 + As_2\,O_3 + H_2\,SO_4$.

96.—How would you distinguish Baryta, Zinc, Alumina, and Lead in the same solution ?

97.—How may Cadmium and Copper be distinguished from each other in solution?

98—Give the tests by which Cobalt, Nickel, Iron, Tin, and Mercury may be detected in the same solution.

99.—How may the following metals be respectively identified before the blowpipe:—Manganese, Silver, Bismuth, Alumina, Zinc, Lead, Tin Copper, Cobalt and Nickel?

100.—Explain these equations :—

(1). $S_2\,K_2 + (HCl)_2 = SH_2 + (Cl\,K)_2 + S$.
(2). $(Ba\,O_2\,H_2)_6 + I_{12} = (IO_3)_2\,Ba + (I_2\,Ba)_5 + (H_2\,O)_6$.
(3). $(Mn\,O_4\,K_2)_3 + (H_2\,O)_2 = Mn_2\,O_8\,K_2 + Mn\,O_2 + (HKO)_4$.
(4). $Cr\,O_3 + (HCl)_6 = Cr\,Cl_3 + Cl_3 + (H_2\,O)_3$.

101.—Explain the following equations :—

(1). $(CrO_3)_2 + (HCl)_6 + (H_2S)_3 = Cr_2Cl_6 + S_3 + (H_2O)_6$.

(2). $Cr_2(SO_4)_3 + [(NH_4)_2S]_3 + (H_2O)_6 = Cr_2O_6H_6 + (SO_4(H_4N)_2)_3 + (H_2S)_3$.

(3.) $Al_2Cl_6 + (NH_4)_2S)_3 + (H_2O)_6 = Al_2O_6H_6 + (H_2S)_3 + (ClNH_4)_6$.

(4). $(PO_4Na_3H)_2 + (SO_4Cu)_3 = (PO_4)_2Cu_3 + (SONa_2)_2 + SO_4H_2$.

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